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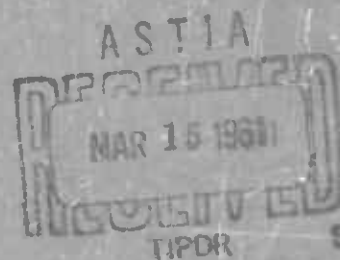
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**FOURTH
SEMIANNUAL REPORT**

TO

CONGRESS

61-2-3
XEROX



APRIL 1, 1960 THROUGH
SEPTEMBER 30, 1960

*National Aeronautics
and Space Administration*

WASHINGTON 25, D. C.

**FOURTH
SEMIANNUAL REPORT
TO
CONGRESS**



APRIL 1, 1960 THROUGH
SEPTEMBER 30, 1960

N A T I O N A L
A E R O N A U T I C S
A N D S P A C E
A D M I N I S T R A T I O N



OFFICE OF THE ADMINISTRATOR
1520 H STREET NORTHWEST
WASHINGTON 25, D.C.
TELEPHONE: EXECUTIVE 3-3260 TWX: WA 755

IN REPLY REFER TO

12 January 1961

The President
The White House

Dear Mr. President:

This Fourth Semiannual Report of the National Aeronautics and Space Administration, covering the period April 1 through September 30, 1960, is submitted to you for transmittal to the Congress in accordance with the National Aeronautics and Space Act of 1958, Section 206(a).

Progress in NASA's aeronautics and space programs is summarized in the introduction. The agency's major activities are reported in detail in the chapters that follow.

During the two years since NASA's inception (October 1, 1958), the staff has simultaneously had to plan, organize, and conduct research and development and operational programs -- programs bold and imaginative and at the same time realistic enough to be carried out with reasonable prospects of success. During this formative period, the agency has drawn together into a vigorous organization numerous Government scientific and technical units possessing substantial space research capabilities. NASA also has been taking increasing advantage of the resources of private research and educational groups. Moreover, despite its own growth, NASA is pursuing a policy whereby private industry is utilized for an ever-larger share of the agency's program.

The Nation can well be proud of NASA's operational achievements. As of early December 1960, the agency had launched 29 earth satellites, of which 15 were still in orbit. Ten of the 15 were still transmitting data. Two U.S. spacecraft were in solar orbit.

Several attempts to send payloads to the vicinity of the moon, however, have ended in failure. Only Pioneer IV, which passed within

The President

12 January 1961

37,300 miles of the moon in March 1959, achieved some of its objectives. Despite the setbacks to be expected in any research and development program in such a new, fast-breaking field, the information transmitted by these satellites and spacecraft has already proven of far-reaching scientific significance.

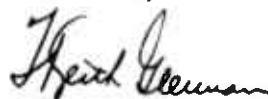
From the mile-upon-mile of telemetered data, we are learning more about the ocean of air in which we live, and about the limitless space beyond. We are also learning much about the earth itself -- its true shape and the composition of its interior.

NASA has now moved out of its formative stage. Within the framework of a Long-Range Plan for space exploration, which the agency prepared and set in motion in 1960, NASA is pursuing a program with three principal objectives:

- 1) early application of earth satellites to practical uses;
- 2) study of the space environment and celestial bodies to gain scientific knowledge;
- 3) determination of man's capacity to function usefully in the space environment, in order to open the way to manned exploration of space, of the moon, and of planets in our solar system.

History may well view our space effort as the first major revolution in the affairs of mankind conceived, and in large measure guided by, scientists. It is clear that the present decade will witness rapid expansion of the frontiers of knowledge with resultant benefits to peoples of all nations.

Sincerely,



T. Keith Glennan
Administrator

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A flood-lit Delta launch vehicle is poised on its launch pad prior to placing the Echo I communications satellite into orbit.

SECTION I

**PROGRESS IN NASA AERONAUTICS
AND SPACE PROGRAMS**

Introduction and Highlights

SUMMARY OF PROGRESS

NASA pursued aeronautical research and space research and development across a broad front during the April 1 - September 30, 1960 period covered by its Fourth Semiannual Report. Initial experiments with the Echo I communications satellite and the TIROS I weather satellite yielded encouraging results, indicating the feasibility of operational systems. Other activities ranged from work on VTOL (Vertical Take-Off and Landing) aircraft to planning for spacecraft missions to the moon and beyond.

The X-15 rocket-powered airplane set world speed (2,196 mph) and altitude (136,500 feet) records with an engine several times less powerful than the final version on which its design performance is based.

Saturn, the giant launch vehicle which shares top priority with Project Mercury, completed in satisfactory fashion its first series of static tests one month ahead of schedule. Meanwhile, other members of NASA's new fleet of standardized launch vehicles began moving on line to replace the older vehicles which owed their parentage to components developed in either the Department of Defense missile program or Project Vanguard.

The Delta vehicle completed its first successful launch when it propelled the Echo I inflatable sphere into orbit. Scout was being readied for its second full-scale flight test after one partly successful launch.

The production model of the Project Mercury flight capsule entered the shakedown, or qualification stage. The capsule passed a flight test of its rocket-equipped escape tower, with the combination showing good aerodynamic stability. An entry test to qualify the capsule structure and heat protection system ended when a malfunction occurred about one minute after lift-off, resulting in destruction of the Atlas launch vehicle.

The seven Mercury astronauts continued intensified training preparatory to the first manned Redstone ballistic flight and the first manned orbital flight in 1961.

The worldwide Mercury Tracking and Ground Instrumentation Network progressed on schedule toward completion early in 1961. Formal agreements for all NASA tracking stations abroad had either been signed or were in final stages of negotiation by the end of September.

Other international developments included: 1) discussions with Australia, Great Britain, France, and Spain concerning use of their air-sea rescue units in Project Mercury; 2) participation by many foreign scientists in the Echo I experiment; 3) discussions and/or agreements with Australia, Canada, Chile, Italy, Japan, and the United Kingdom, among others, concerning cooperative space projects.

The Launch Operations Directorate (LOD) was created within the Office of Launch Vehicle Programs to facilitate standardization of launch operations and facilities. LOD will launch most NASA vehicles and support the launch operations of the remainder.

The NASA Long Range Plan continued to serve as the guide to advanced missions including those of Ranger, Surveyor, Prospector, and Mariner spacecraft. Ranger will land the first survivable payloads on the moon; Surveyor and Prospector will make controlled landings on the moon; and Mariner will carry out deep penetrations of interplanetary space, including missions to Venus and Mars.

NASA's Committee on Long Range Studies has set in motion, through contracts to private research organizations, a series of studies concerning the wide-ranging implications of space exploration, including practical applications and legal aspects.

NASA's personnel increased from 9,755 to 15,603, the rise for the most part reflecting the transfer to NASA of the Army Ballistic Missile Agency's Development Operations Division (Marshall Space Flight Center), Huntsville, Ala.

Highlights of NASA aeronautical and space activities during the report period follow:

...April 1 -- TIROS I (Television Infra-Red Observation Satellite), a 270-pound experimental weather satellite, was launched by a Thor-Able from AMR, attaining a near-circular orbit with a perigee of 428.7 miles, an apogee of 465.9 miles. TIROS I made meteorological history between April 1 and June 29 when its two television cameras transmitted 22,952 photographs of cloud cover and other phenomena of value to weathermen.

...April 29 -- Interim or formal agreements for all overseas Mercury tracking stations were concluded and construction had started on the sites by June 30.

...May 6 -- Maj. Robert M. White, USAF, flew X-15 No. 1 to an altitude of 60,800 feet and a Mach number 2.2.

...May 9 -- The first production model of the Project Mercury capsule was test flown in a simulated "pad abort" at Wallops Station to check the escape system, landing system, and post-landing equipment.

...May 12 -- NASA pilot Joseph Walker flew X-15 No. 1 to 78,000 feet and a speed of Mach 3.2.

...May 13 -- The first attempt to orbit a 100-foot diameter Project Echo passive communications satellite ended when the attitude control jets in the second stage of the Delta vehicle apparently malfunctioned.

...June 8 -- While undergoing ground tests by the contractor, North American Aviation, Inc., the fuel and hydrogen peroxide tanks of X-15 No. 3 exploded on the stand. Contractor pilot Scott Crossfield was uninjured.

...June 15 -- The first series of Saturn static tests was completed with a 122-second firing of the complete prototype eight-engine first stage at the Marshall Space Flight Center.

...June 26 -- The last communication with the Pioneer V space probe, a six-minute message, was received at Jodrell Bank. At that point, the probe was an estimated 22,462,740 miles from earth. Pioneer V was launched on March 11.

...July 1 -- The Development Operations Division of Army Ballistic Missile Agency, Huntsville, Ala., was transferred officially to NASA and became the George C. Marshall Space Flight Center.

...July 1 -- The first complete four-stage Scout was launched from Wallops Station. The first three stages performed satisfactorily but fourth stage ignition was prevented by command signal from Wallops when faulty radar indicated wrongly that the vehicle was deviating from its course.

...July 29 -- An Atlas launch vehicle exploded during an attempted entry test that was to have qualified the structure and the heat protection system of the Mercury production capsule.

...August 4 -- X-15 No. 1 set a new world speed record of 2,196 mph -- more than three times the speed of sound (Mach 3.31). NASA pilot Walker was at the controls.

...August 12 -- With Maj. White piloting, X-15 No. 1 reached a world altitude record of 136,500 feet, surpassing the previous record of 126,200 feet set in 1956 by the X-2.

...August 12 -- Echo 1, the first passive communications satellite, was launched by a Thor-Delta from AMR. The 100-foot-diameter inflatable sphere was used to relay voice messages, facsimile photographs, teletype signals, and two-way telephone conversations. Transcontinental and trans-Atlantic signal relays were completed, and experiments were conducted to learn more about the effects of the ionosphere on radio signals.

...September 19 -- The first of a series of NERV (Nuclear Emulsion Recovery Vehicle) experiments to provide detailed analysis of the lower portion of the Great Radiation Region was launched from Point Arguello, Calif. The NERV capsule reached an altitude of 1,260 miles. It was recovered in the Pacific, 1,300 miles from the landing point.

...September 30 -- Formal agreements for all NASA tracking stations, planned at present, were either concluded or near conclusion.

TABLE 1 -- NASA Satellite and Probe Launchings
April 1, 1960 - September 30, 1960

Name, By, Type, Orbit Weight, Payload Weight	Launch Date and Lifetime	Launch Vehicle	Payload Instrumentation	Test Results	Perigee (Miles)	Apogee (Miles)
TIROS (Television and Infra- Red Observation Satellite) 1* (1960 Beta 2)	Apr. 1, 1960 -- (50 - 100 years in orbit)	Thor-Able	Dimensions: 42 inches in di- ameter; 19 inches high; cylin- drical in shape. Experiments: Two TV systems, one wide angle, one narrow angle, photograph cloud cover and transmit images to earth.	Over 22,000 photographs of cloud cover were transmitted between Apr. 1, 1960 and June 17, 1960, when photo interro- gation ceased. Meteorologists hailed the satellite as opening new and advanced vistas in weather forecasting and study.	435**	468**
U.S. meteorological satellite	(Scientifically useful lifetime was 78 days.)	Stages: 1st: Modified USAF Thor 2d: Liquid-fuel engine modified from Vanguard. 3rd: Solid-fuel rocket modified from Vanguard. Special radio beacon to aid in tracking.	Other instruments: Teleme- try, command, and an attitude sensor system. Shell composition: Aluminum and stainless steel. Antennas: Turnstile trans- mitting; one receiving.	Period: 99.19 minutes Speed: Approx. 17,000 mph. Orbital path: Approx. 27,000 miles.		
Launched from: AMR, Cape Canaveral, Fla.		Gross lift-off weight: Approx. 150,000 lbs.	Transmitters: For tracking purposes and providing infor- mation on attitude, equipment operation and environment, two 30-mw beacon transmitters oper- ating on 108.00 mc and 108.03 mc. Connected to each TV sys- tem is a 2-watt FM transmitter operating at 235.00 mc for re- laying picture information.	Launch Inclination: 48.327° to the Equator.		
Orbit weight: 270 pounds. Total payload weight: 270 pounds.		Height: 90 feet Diameter at base: 8 feet	Power supply: Nickel cadmium batteries charged by solar cells. Transmitter lifetime: 300 hours.			

The satellite is covered on its
top and sides with over 9200
solar cells. Projecting from
the top center is a receiving
antenna; around the baseplate
are three pairs of spin rockets
and three transmitting antennas.

* This is the first of two TIROS satellites scheduled for 1960. It is not equipped with infra-red radiation sensors to map relative temperatures of the earth's surface. Both satellites are experiments to determine whether meteorological satellites are feasible and to refine instruments and techniques for an operational meteorological satellite system.

** Initially.

Note: Distances are in statute miles. Except where indicated, the chart does not include descriptions and weights of spent rocket castings, etc., that have gone into orbits or flight trajectories along with payloads.

TABLE 1 (Continued)
April 1, 1960 - September 30, 1960

Name, By, Type, Orbit Weight, Payload Weight	Launch Date and Lifetime	Launch Vehicle	Payload Instrumentation	Test Results	Perigee (Miles)	Apogee (Miles)
Echo	May 13, 1960 -- 0	Delta	Shell composition: Sphere fabricated of 1/2 mil (.0005 inches) thick plastic film, upon which is vapor-deposited alum- inum to provide radio wave reflectivity of 98 percent up to frequencies of 20,000 mc. The sphere contained 4 pounds of benzoic acid, a powder which turns to a gas and expands in near-freezing temperatures. This subliming powder is re- sponsible for sphere inflation.	First stages of Delta performed correctly. Second stage power- flight was apparently correct, but telemetry data indicates that halfway through the coast- ing period, the attitude control jets in the second stage mal- functioned. Third stage did not ignite. Orbit was not achieved. Launch Inclination: 47° from the Equator.	0	0
U. S. experimental com- munications satellite		Stages: 1st: Modified Thor; liquid- fueled; 150,000 pounds thrust. 2nd: Engine modi- fied from second stages of Vanguard and Thor-Able; liquid-fueled; 7,500 pounds thrust; radio- command guidance system. 3rd: Solid- propellant rocket originated in Vanguard and used in Thor-Able; 3,000 pounds thrust.	Experiment: The inflatable sphere was to be placed in a 1,000 mile altitude circular orbit and used as a reflector of UHF radio signals in com- munications experiments. Dimensions: At launch, satellite was packaged in 26-1/2 inch magnesium sphere. The container was to open in orbit, releasing the inflatable plastic sphere which would expand to a 100-foot diameter.			
Launched from: AMR, Cape Canaveral, Fla.						
Total payload weight: 190 pounds, including: 1) Plastic sphere - 132 pounds 2) Vaporized aluminum - 4 pounds 3) Subliming powder for inflation - 30 pounds 4) Container - 24 pounds						

TABLE 1 (Continued)
April 1, 1960 - September 30, 1960

Name, By, Type, Orbit Weight, Payload Weight	Launch Date and Lifetime	Launch Vehicle	Payload Instrumentation	Test Results	Perigee (Miles)	Apogee (Miles)
Echo 1 (1960 lota 1) U. S. experimental communications satellite Launched from: AMR, Cape Canaveral, Fla. Total payload weight: See Echo experiment of May 13, 1960. Total orbital weight: 166 pounds including polymer plastic sphere, vapor- deposited aluminum, and sublimating powder for inflation. Also in orbit is the 50-pound empty third stage casing of the Delta launch vehicle.	August 12, 1960 -- (Indefinite)	Delta See Echo experi- ment of May 13.	See Echo experiment of May 13, 1960. Additional instrumentation: To aid in tracking, two 10-mw beacons operating at 107.94 mc were attached to opposite sides of the sphere. Each beacon is equipped with 70 solar cells which recharge a power source of 5 nickel cadmium batteries. Each beacon assembly weighs 11 ounces, is 10 inches in di- ameter, and is three-eighths inch thick. A 60-mw transmitter oper- ated at 108.06 mc was at- tached to the Delta third stage to aid in tracking. Mercury batteries powered this transmitter.	Orbit attained. Both transcon- tinental and trans-Atlantic voice and radio signals were trans- mitted via the satellite. Two- way telephone conversations were held between Goldstone, Calif., and Holmdel, N. J., via the sphere. The voices were said to come in as clear as in a local call. Numerous other transmissions were ac- complished both in the U. S. and abroad. Period: 118.3 minutes Velocities: Perigee: 15,973 mph Apogee: 15,643 mph Orbital path: Approx. 31,500 miles Inclination: 47.2° to the Equator.	945*	1049*

* On Aug. 15, 1960.

TABLE 1 (Continued)

April 1, 1960 - September 30, 1960

Name, By, Type, Orbit Weight, Payload Weight	Launch Date and Lifetime	Launch Vehicle	Payload Instrumentation	Test Results	Perigee (Miles)	Apogee (Miles)
Pioneer	Sept. 25, 1960 -- 0	Atlas-Able	Dimensions: 39 inches in diameter with four 24-inch-by-24-inch square solar vanes jutting from probe's equator. Experiments: 1) Measurements of 3 specific energy levels of cosmic rays; 2) plasma experiment; 3) scintillation spectrometer; 4) sun scanner; 5) solar cells (8,800 in all); 1,200 on each side of four solar vanes to create voltage to recharge the probe's chemical batteries in flight (Note: electronic gear in probe includes: 2 transmitters and 2 receivers); 6) micro-meteoroid detector; 7) two types of magnetometers. <u>Antennas:</u> 4 dipole aluminum rods.	Erratic burning in second stage resulted in inadequate velocity. Orbit was not achieved.	0	0
U. S. Lunar Probe (Paddle-wheel sphere with four solar vanes or paddles). Scientific payload: 387 pounds.		Stages: <u>1st:</u> U. S. Air Force Atlas ICBM modified to accommodate extra stages. <u>2nd:</u> Liquid propellant, adapted from earlier Able rocket vehicles. <u>3rd:</u> Solid propellant modified from earlier Able and Vanguard rocket configurations. <u>Gross lift-off weight:</u> 260,000 pounds plus. <u>Height:</u> 98 feet. <u>Diameter at base:</u> 16 feet.				
<u>Mission:</u> To investigate environment between Earth and Moon and develop technology for control of spacecraft on lunar and interplanetary journeys.						
			<u>Transmitters:</u> 2 ultra-high frequency 378 mc transmitters at 1.5 watts. <u>Power supply:</u> Nickel cadmium batteries rechargeable by solar cells (see above). The payload also contained a small hydrazine-powered engine to provide in-flight velocity corrections. The engine had two thrust chambers, one to step up velocity, the other to supply reverse thrust when probe approached Moon's gravitational field. Each chamber could deliver 20 pounds of thrust.			

SECTION II

SPACE FLIGHT PROGRAMS

Satellite Applications

WEATHER AND COMMUNICATIONS SATELLITES PROVE FEASIBLE

Successes of NASA's Echo I communications satellite and TIROS I meteorological satellite have ushered in the era of practical application of space technology. The two experiments demonstrated that use of satellites as worldwide teleradio links and global weather observation systems is technically feasible.

While these projects were being carried forward, NASA rounded out planning for satellites evolved from, or related to, Echo and TIROS. Included are a second TIROS and the Nimbus series of weather satellites, as well as further development of passive communications satellites of the Echo type.

NASA is also studying the potentialities of active communications satellites. These would be equipped with radio receivers, transmitters, and antennas, plus batteries, devices for converting sunlight into electricity, or other auxiliary power sources. The active satellite would receive messages from ground stations and repeat them instantaneously to distant parts of the earth.

COMMUNICATIONS SATELLITES

World Communications Systems Becoming Inadequate

Capacities of international teleradio and cable systems are severely burdened today and will probably be exceeded by the demands of tomorrow. At present, television cannot be transmitted directly more than two or three hundred miles. However, the usable radio spectrum of frequencies above 20 mc. (whose range is limited to line-of-sight) offers almost unlimited bandwidth space. Ground-based microwave relay links and coaxial cables are employed to overcome the range limitation but for overseas communications they are impractical, or prohibitively expensive.

Such prototypes as NASA's Echo I have demonstrated conclusively that satellites, employed as communications relays or reflectors, can extend line-of-sight transmissions

to intercontinental ranges. Satellites can provide tremendous bandwidth capacity to meet the fast-growing need for teleradio communications. Their use would also permit rapid, voluminous transmission of scientific data to the electronic computers that are playing more and more significant roles in the workings of government, science, and industry. One industry source estimates that a single communications satellite, costing about \$40 million and placed in a 22,300-mile equatorial orbit, could accommodate as much traffic as a \$500-million cable system.

Project Echo

During the past two years, NASA has conducted a series of experiments leading to Echo I. This highly successful, developmental satellite is a large, inflatable sphere that reflects or bounces back to earth radio signals from ground stations. (See NASA's Third Semiannual Report to Congress, Chapter 7, Satellite Applications, for details of suborbital tests through March 31, 1960.)

Vertical Flight Test Successful -- Continuing the sub-orbital flight tests of the Echo payload, the fifth launch from Wallops Station on May 31, 1960, was according to plan. A Sergeant rocket was employed as first stage, two Recruit rockets for liftoff assistance, and a Delta X-248 rocket as second stage. The flight, which tested ejection and inflation of the Echo payload, was the first with battery and solar-powered radio beacons attached to either side of the sphere.

In the vertical test, the sphere inflated without rupture and both beacons functioned as intended, despite the fact that the second stage separated and fired prematurely before despin. As a result, the sphere inflated while the container was still spinning at about 90 rpm.

First Experiment Unsuccessful -- The first Echo payload was launched from AMR on May 13, 1960. The Delta second-stage autopilot failed during the coasting phase and the payload did not orbit. The third-stage engine did not fire nor did the payload separate.

Echo I Achieves Planned Objectives

Injected into Nearly Circular Orbit -- On Friday August 12, at 5:39 a.m. EDT, NASA launched Echo I, the world's first successful passive communications satellite. The magnesium capsule, containing the inflatable, 100-foot-diameter, aluminized plastic sphere was carried aloft from

AMR by a Delta launch vehicle. Injection of the 137.4-pound satellite (containing an additional 30 pounds of subliming chemicals) into a nearly circular orbit and inflation to its full diameter were confirmed when word of a sighting was received from tracking station at Woomera, Australia. Echo's initial apogee was 1,049 miles and its perigee 945 miles. Its initial orbit period was 118.3 minutes. (For details of launching, see pp. 77-78).

President's Voice Relayed Via Sphere -- During Echo's first orbit, scientists proved the passive communications satellite's capabilities as a "radio mirror" by transmitting President's Eisenhower's tape-recorded voice from California to New Jersey via the sphere. In his message, the President invited other nations to use the satellite for similar experiments. This transmission originated from JPL's Goldstone, Calif., station as they tracked the satellite eastward. The message was received by the Bell Telephone Laboratories at Holmdel, N.J.

Many Experiments Conducted with Echo -- Since then, numerous communications experiments have been conducted by the many participants in the Echo program. Transmissions have included teletype signals, facsimile photographs, two-way telephone conversations using commercial equipment, transcontinental and trans-Atlantic signal relays, and experiments to learn more about the effects of the ionosphere on radio signals.

Orbital Computations -- Computations for the orbit of Echo are being handled by IBM 709 computers at NASA's Goddard Space Flight Center, Greenbelt, Md., and are made available to interested observers around the world with the help of the Voice of America. Orbital speed of the satellite averages about 16,000 miles per hour. When Echo passes overhead, it is visible as a star-like body, about as bright as Vega. Hence it has been viewed by hundreds of thousands of observers in both hemispheres.

First Intercontinental Radar Signal Relayed -- A large experimental radar at Trinidad, B.W.I.F.,* operated by the Rome Air Development Center (RADC), Rome, N.Y., successfully bounced the world's first intercontinental radar signal off Echo on the morning of the launch. The signal was transmitted to a receiving station at Floyd, N.Y., via the sphere, on its first orbit at 7:58 a.m. The experimental radar at the RADC test site was the first to track the sphere and confirm its inflation.

* Off the coast of Venezuela.



The .0005-inch thick aluminized plastic, which served as the shell of the Echo 1 communications satellite, is inspected prior to satellite fabrication.

Trans-Atlantic Radio Transmission -- On August 18, the Bell Telephone Laboratories, Holmdel, N.J., announced the completion of the first trans-Atlantic wireless-code transmission via Echo from Holmdel, N.J., to a station at Issy-les-Moulineaux, France.

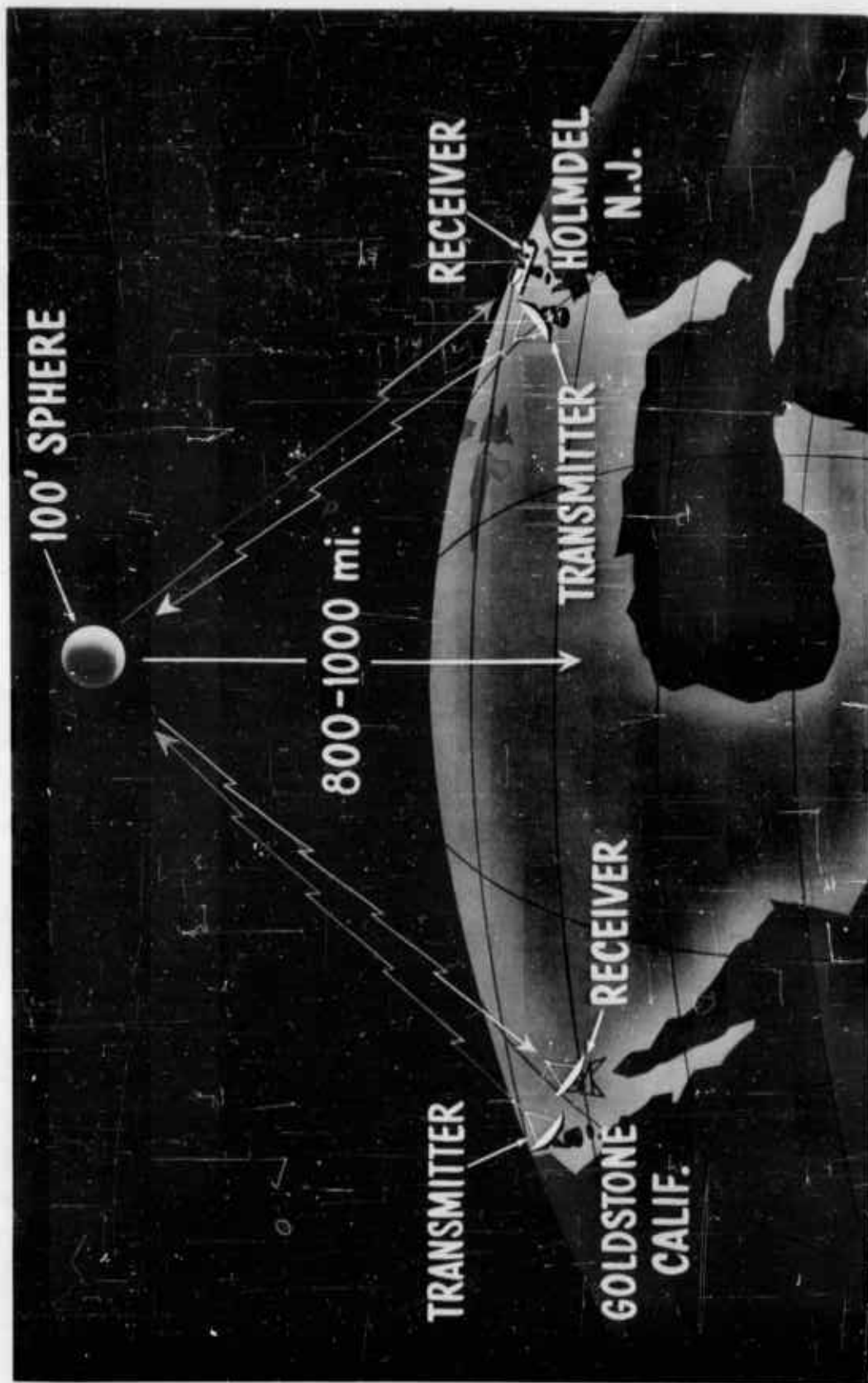
Wirephotos Bounced from Satellite -- Early on August 19, a wirephoto of President Eisenhower was beamed to Echo and received back on earth. The signals were transmitted to the satellite by an Associated Press wirephoto transmitter connected to an antenna at Collins Radio Company's headquarters in Cedar Rapids, Iowa. An antenna of the Alpha Corp., a Collins subsidiary near Dallas, Tex., acquired the returning signals, which were fed into an AP wirephoto receiving unit. Picture transmission was completed in less than five minutes, at the same speed as wirephotos move on the trans-continental network -- about one minute per inch of picture width. On September 22, a similar technique was used to relay a photo of members of the Federal Communications Commission, with NASA Administrator Glennan. The photo was transmitted by land-line to the U.S. Naval Research Laboratory at Stump Neck, Md., bounced off the Echo satellite, and back to the point of origination, the Bell Telephone Laboratories at Holmdel, N.J.

Trans-Atlantic Voice Message Relayed -- On the night of August 23, space scientists bounced the first trans-Atlantic voice message off Echo I -- a description of the Echo experiment. They also transmitted a recording of "America, the Beautiful," to listeners in England. The transmission began at 7:14 p.m. EDT, between the Holmdel station and the Jodrell Bank experimental station in Lower Withington, Cheshire, England.

Echo Enters Earth's Shadow -- Echo entered the earth's shadow for the first time on August 24 at 5:25 a.m. EDT. The satellite will again be in continuous sunlight for a period starting in January 1961.

Sunlight Shifts Orbit -- By August 22, NASA had determined that the pressure of sunlight against Echo was pushing the low point of its orbit one and one-half miles closer to earth each 24 hours.* Sunlight exerts against the sphere a pressure of about one-third of a gram -- roughly the weight of a dried bean. Because the satellite is so large and yet so light, sunlight pressure has enough

* A similar, but far less drastic effect, has been noted on the orbit of Vanguard I, launched on March 17, 1958.



Schematic portrayal of transcontinental communication via the Echo satellite by the Jet Propulsion Laboratory radar station at Goldstone, Calif., and the Bell Telephone Laboratory station at Holmdel, N. J.

effect on it to be readily observed. The daily change in the satellite's near point, or perigee, increasing daily, will be doubled in a matter of weeks. Then, however, the rate will decrease and the sunlight pressure will eventually change direction, because of the changed relation of the sun, the earth, and the Echo orbit. This will raise the perigee and lower the apogee to a more nearly circular orbit.

Radio Beacons Operating Only in Sunlight -- As a tracking aid, two radio beacon transmitters are attached to the outer surface of the satellite. Early in Echo's life, the nickel-cadmium storage batteries that powered the beacons during periods of darkness apparently failed. During sunlight periods, the radios continue to operate, powered directly from 70 solar cells in each transmitter assembly. For the last few weeks, Echo has been in darkness about 30 minutes out of each 118-minute orbit. The storage battery failure may have been caused by the extremes of temperature encountered by the satellite -- ranging from 80 degrees below zero (Fahrenheit) while in darkness, to about 240 degrees above zero in sunlight.

Loses Roundness But Still Bounces Radio Waves -- The earth's shadow apparently has little effect on the roundness of the satellite, indicating that it is structurally sound even though made of non-rigid material. By September 3, despite wrinkles crisscrossing its surface, the big sphere's effectiveness as a radio reflector had scarcely been impaired. The surface wrinkling was first noticed when observers began to report that the satellite seemed to twinkle. When Echo first went into orbit, it shone with a much steadier glow.

Internal Pressure Loss -- Apparently the wrinkling followed the loss of some of the internal gas pressure which had been produced by the vaporization of 10 pounds of benzoic acid and 20 pounds of anthraquinone. The chemicals had been inserted in the uninflated sphere in powder form before launching; in the low temperature and near-vacuum of space, they changed to gas and inflated the satellite after it was injected into orbit. Some gas leaked out through 243 tiny holes deliberately pierced through the surface before launching to prevent sudden over-inflation while the sphere was being placed in orbit. Because the total area of the pinholes amounts to only $\frac{3}{4}$ of a square inch out of a total of 31,000 square feet of plastic, much of the gas remained inside.

Perforations from Micrometeoroids -- Still other perforations have been caused by micrometeoroids and cosmic

dust. About four days after launch, Echo's path took it repeatedly through the annual Perseid meteor shower, a trail of cosmic debris that appears to radiate from the direction of the constellation Perseus. This litter (now in orbit around the sun) was left behind by Comet 1862 III. Other artificial satellites have been bombarded by space debris. The Soviet Union's Sputnik I passed through a similar shower in mid-October 1957, and was apparently hit but not damaged. Echo I is much more vulnerable to puncture than any of its predecessors because it is composed of thin plastic film.

Radar Tracking Still Possible -- Although the radio beacons are no longer operating when Echo is in darkness, the satellite can still be tracked by radar during such periods. Tracking continues at Bell Telephone Laboratories; JPL's Goldstone Station; the Air Force's radar test site at Trinidad, B.W.I.F., and Lincoln Laboratory's Millstone Hill radar station, Westford, Mass. Optical tracking is provided by the Smithsonian Astrophysical Observatory, Cambridge, Mass. Recent radar measurements indicated the reflective area of Echo I to be approximately the same as it was on the day of launching. Its orbit has remained remarkably stable. The satellite is expected to remain in orbit about a year.

Cooperation With Voice of America -- Through the Voice of America, the U.S. Information Agency's radio network, NASA has provided orbit information for viewing Echo I in foreign lands.

Echo Program Management

Project Echo is managed by Goddard Space Flight Center, assisted by Langley Research Center. Goddard is responsible for: 1) furnishing tracking data to experimenters; 2) monitoring communications experiments; 3) research and development for communications techniques and components; and 4) development of payloads for multiple launchings of communications satellites. Development, fabrication, packaging, and installation of the Echo I payload was the responsibility of Langley. In addition, Langley is studying and developing long-lived, erectable passive satellites of advanced types.

Participation in Project

The chief participants in communications experiments with Echo I are NASA's Jet Propulsion Laboratory, the Bell

Telephone Laboratories under contract to NASA, and the Naval Research Laboratory. Lincoln Laboratory of MIT is assisting in tracking and evaluating the results of experiments. Goddard Space Flight Center is responsible for tracking Echo I and for furnishing antenna pointing directions. Many volunteer organizations, institutions, and foreign governments are taking part in the communication experiments and are exchanging information related to NASA communications satellite programs.

Rigidized Inflatable Structures for Later Communications Satellites

Contract Awarded -- Anticipating the need for increasing the lifetimes of inflatable satellites, NASA is designing and developing means of fabricating structures that will maintain their reflective characteristics in sunlight or shadow. A seven-month contract for developing techniques to rigidize such structures was awarded the Hughes Aircraft Co., Culver City, Calif., on July 15. Test panels will be fabricated and "flown" in a wind tunnel at Langley Research Center to simulate rigidization.

Results Show Promise -- The results of this work to date show promise that effective techniques can be developed. Plans are under way to fabricate a rigidized payload for launching in 1962.

METEOROLOGICAL SATELLITES

TIROS I

NASA is developing meteorological satellites to provide worldwide observation of atmospheric elements -- the data meteorologists must have to understand atmospheric processes and to predict the weather. TIROS I, launched April 1, 1960, was the first step toward an operational meteorological satellite system. The highly successful 270-pound satellite, orbiting at altitudes averaging 450 miles, transmitted 22,952 television pictures of the earth's cloud patterns. This gave meteorologists unprecedented opportunity to relate the earth's cloud cover to weather observations from the ground. (For details of TIROS I launching, see NASA's Third Semiannual Report to Congress, Chapter 3, Experimental Missions.) TIROS proved it is feasible to employ satellites for observing clouds, cloud patterns, and related atmospheric conditions.

Data Analysis -- The U.S. Weather Bureau and other cooperating meteorological groups will be analyzing TIROS I data for months to come. Already these data have made important contributions to meteorological research. For example, TIROS transmitted pictures of cyclonic storms, or vortices, whose spiral bands were more than 1,000 miles in diameter. The frequency and extent of highly organized cloud systems associated with these vortices were by no means fully realized before TIROS.

Other pictures indicated the cloud bands associated with jet streams, regions of moist and dry air, thunderstorms, fronts, and many other meteorological phenomena. Experimental use of TIROS pictures in practical meteorological analysis has resulted in increased accuracy, particularly in areas such as those over the oceans where it is difficult to obtain sufficient data by orthodox means.

Of the 22,952 pictures which TIROS transmitted, 17,449 were received at Fort Monmouth, N.J., -- 4,698 from the narrow-angle camera, 12,751 from the wide-angle camera. Kaena Point, Hawaii, received 5,503 frames -- 1,117 from the narrow-angle camera, 4,386 from the wide-angle camera. Of the total, it is estimated more than 60 percent were of good quality, useful to meteorological research.

Interrogation Halted -- The decision to discontinue interrogating TIROS I was made after orbit 1,302 over Fort Monmouth, about midnight Wednesday, June 29. The wide-angle camera system and all telemetry had ceased functioning. (The 108.00-mc tracking beacon continues to operate.) Failure was due to an inoperative relay in the wide-angle camera system that drained the batteries and caused the wide-angle transmitter to burn out. This affected the entire satellite system. A few further attempts were made to interrogate the satellite -- for engineering purposes only.

Final Spin Rockets Activated -- On August 18, the third and final pair of rockets that control the spin rate of the meteorological satellite TIROS I were activated on ground command from the Radio Corporation of America's station at Hightstown, N.J. The spin rate increased from $11\frac{1}{2}$ to 13 revolutions per minute.

Second TIROS Planned

NASA plans are proceeding for launching a second, advanced version of the TIROS satellite. The second TIROS satellite will have two infrared sensors in addition to

its two television cameras. Similar to TIROS I in most respects, the second satellite will be spin-stabilized, but will have a magnetic dipole control device installed to permit limited ground control of the spin axis. In the TIROS I experiment, the spin-axis did not remain constant, as had been expected. It is hoped that sufficient ground control of the spin-axis can be obtained to increase the length of time during which the cameras are oriented toward the earth.

Foreign Participation Invited

Late in August, the United States invited scientists of 21 foreign nations to participate in meteorological research connected with the launching of a second TIROS weather satellite. Data obtained, including orbital information, photographs, etc., will be furnished to participants in the project to assist cooperating groups in timing and comparing local weather observations. (For further details see Chapter 9, International Programs, pp.112.)

TIROS Project Management and Participation

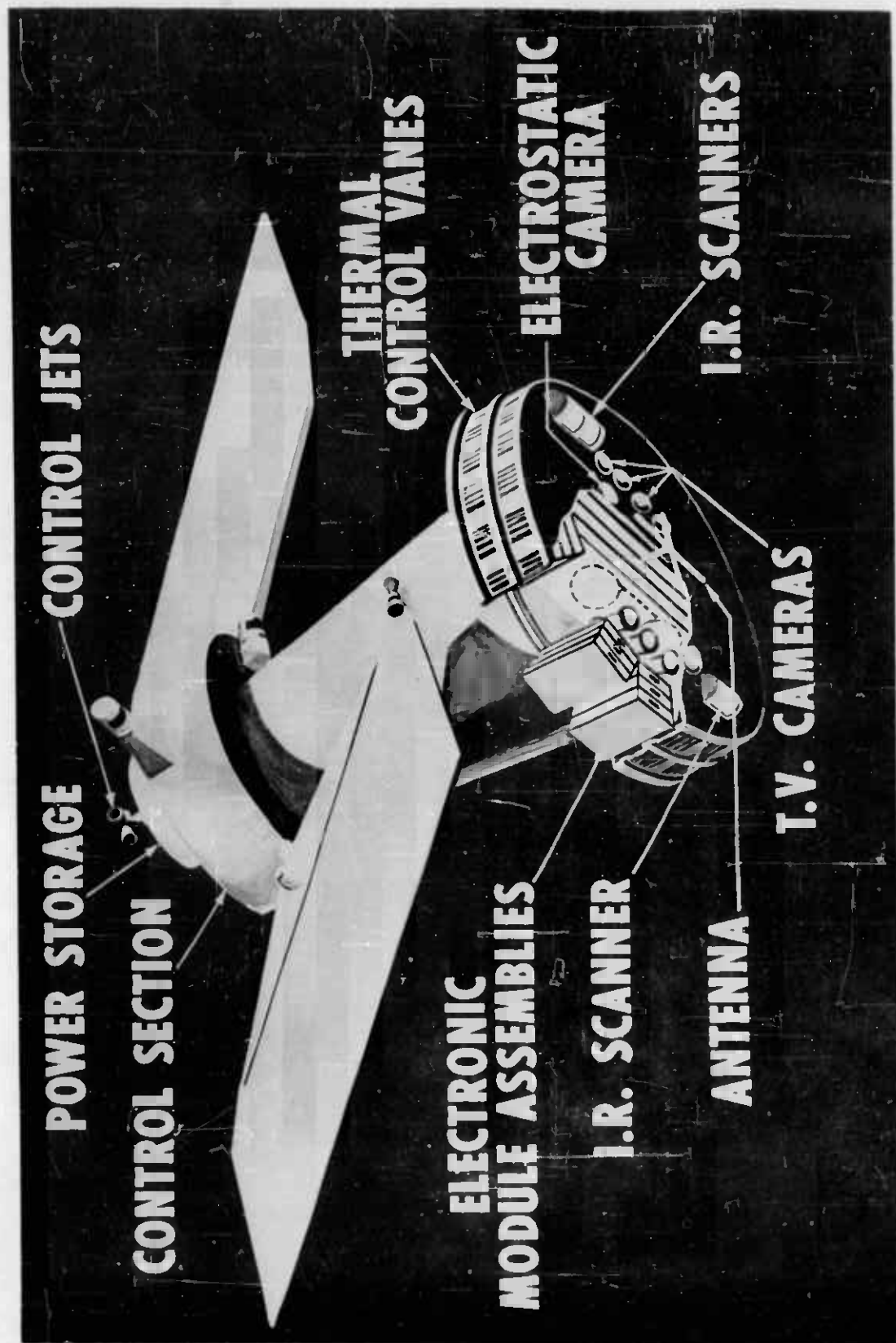
The TIROS program, originated by the Advanced Research Projects Agency (ARPA) of the Department of Defense, was transferred to NASA in the spring of 1959. Goddard Space Flight Center is responsible for: 1) over-all direction and coordination; 2) tracking and orbit prediction; 3) operation of the control center; and 4) development of infrared experiments for payloads. The Astro-Electronics Division of the Radio Corporation of America, Hightstown, N.J., is developing integrated payloads and selected ground equipment, and is providing supporting services for post-launch ground operations. On the East Coast, pictures are acquired by the U.S. Army Fort Monmouth facility. For TIROS I, a second data acquisition station was at Kaena Point, Hawaii, operated by Lockheed Missile Systems Division for the Air Force Ballistic Missile Division. For TIROS II, the second site will be at the Pacific Missile Range. The Naval Photographic Interpretation Center, in cooperation with the U.S. Weather Bureau, is assisting in locating photographed areas by identifying landmarks and other geographical features. For the second TIROS experiment, Goddard will process infrared tapes and correlate the data with the television pictures. The data will be interpreted in a joint project in which Goddard, the U.S. Weather Bureau, and the Air Force Cambridge Research Laboratory will cooperate.

Nimbus Satellite Development

Experience with TIROS has helped set the course of the next generation of meteorological satellites. This series, designated Nimbus, will have advanced sensor equipment to scan cloud cover and measure infrared radiation from earth. Nimbus will have two features lacking in the TIROS series. It will always face the earth, eliminating the undesirable feature of frequently pointing away from earth, as is the case with the space oriented TIROS satellites. Nimbus will be launched from the Pacific Missile Range into a polar orbit and will thus view the atmosphere over the entire globe; accordingly, Nimbus will provide much greater coverage than did TIROS I which was limited to an area between 50° north and 50° south latitudes.

Nimbus Project Management

During the report period, Project Nimbus was in its earliest stages, under the management of Goddard Space Flight Center. NASA will select contractors for system integration and for the basic structure in the near future. The Nimbus series is being developed as a prototype of a standard, operational satellite system that can provide valuable data for day-to-day meteorological analyses. Improved short- and long-range weather prediction may be expected from this increased observational capability.



Major equipment of Nimbus, a Polar-orbiting meteorological satellite, which will be an advanced successor of the TIROS program.

Manned Space Flight

PROJECT MERCURY IS SPRINGBOARD FOR APOLLO

Project Mercury, first phase of the Nation's manned space flight program, will reveal two essential facts: 1) how usefully a man can function in space flight; and 2) the design and operational problems which must be solved prior to advanced manned space flight.*

Beyond Mercury, and based upon its results, more advanced manned space missions are being planned by NASA. The first will be Project Apollo. As now conceived, the Apollo spacecraft would weigh five to 10 tons and would be capable of carrying three men on either a lunar-orbiting mission or an earth-orbiting space laboratory mission. Apollo would be launched by an advanced version of Saturn.

PROJECT MERCURY PROGRESS

Suborbital Flight Nears

NASA tentatively plans to launch the first manned sub-orbital flight early in 1961, and the first manned orbital flight late in the year. Numerous qualification tests -- using unmanned capsules and capsules carrying specially trained chimpanzees -- will precede the manned flights.

Twenty-Four Capsules Involved

McDonnell Aircraft Corp., the capsule contractor, is fabricating 24 one-ton, bell-shaped capsules for the project. By the end of September, six had been delivered to NASA from the firm's St. Louis, Mo., plant. Of the 24 capsules, two have been launched -- one using the escape rocket during a simulated beach abort on May 9, the other by an Atlas on July 29. Thirteen of the remaining capsules are scheduled for the Atlas, seven for Redstone, one for Little Joe, and one will serve as a spare.

* Background, objectives, and evolution of Project Mercury were detailed in NASA's First, Second, and Third Semi-annual Reports to Congress.

Suborbital and Orbital Flight Plans

The suborbital flight plan calls for a Redstone to launch the manned Mercury capsule on a 15-minute ballistic flight from Cape Canaveral, Fla., at speeds up to 4,000 mph. The capsule will reach an altitude of about 125 miles and a distance of approximately 200 miles, landing in the sea north of the Bahama Islands.

The Redstone will produce a launch acceleration of 6 g followed by a 5 1/2-minute period of weightlessness. The burnout angle and velocity of the launch vehicle will result in an atmosphere entry deceleration of 11 g.

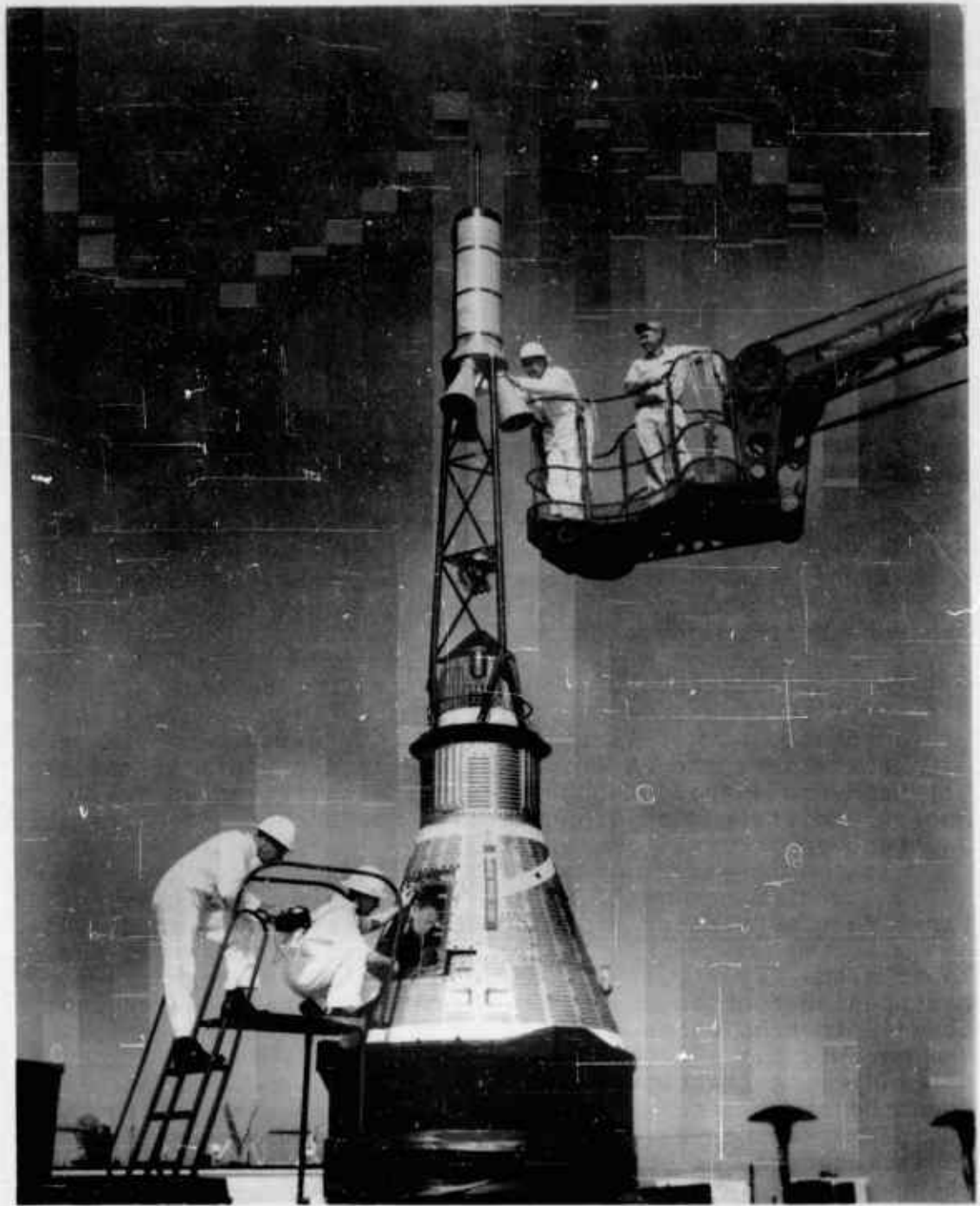
In the orbital flight, an Atlas will launch the Mercury capsule from Cape Canaveral, injecting it into orbit near Bermuda. After three earth orbits (at a speed of about 18,000 mph), the capsule will land in the Atlantic Ocean near Puerto Rico approximately five hours after lift-off.

Progress During Report Period

During this report period, the production model of the Mercury flight capsule entered the "shakedown" or qualification stage, with flights on May 9 and July 29. Training of the seven Mercury astronauts intensified. Organization of the Mercury ground support system -- including tracking and ground instrumentation stations, medical, meteorological, and recovery teams -- moved forward.

First Test of Mercury Production Capsule

In the May 9 test, the capsule, with its rocket-equipped 16-foot escape tower, was mounted on a launch pad at Wallops Station as it would be on the nose of an Atlas. The capsule was attached to an adapter with the same type of clamp ring that will attach the capsule to the Atlas. Then the clamp ring was released by explosive bolts and the escape rocket was fired, launching the capsule vertically at an acceleration of 17 g to an altitude of 2,540 feet. At that altitude -- two seconds after the tower jettison rocket separated the burn-out escape rocket and tower from the capsule -- a drogue parachute stabilized the capsule and dragged out the 63-foot-diameter main cargo parachute. The main chute lowered the capsule into the Atlantic Ocean about three quarters of a mile from the launch site.



Technicians prepare the Mercury capsule for the beach abort test at Wallops Station, Va., on May 9, 1960.

The capsule-escape tower combination showed good aerodynamic stability; no tumbling occurred even though the thrust axis had been deliberately misaligned one-half inch from the center of gravity to move the capsule off to the side away from the launch vehicle.

The capsule was recovered by a helicopter and returned to Wallops 17 minutes after launch. Later it was shipped to the contractor for extensive checking.

Second Production Capsule Test

A July 29 launch of a Mercury production capsule by an Atlas ended in failure when a malfunction occurred about one minute after lift-off, resulting in destruction of the launch vehicle.

The primary objective of the test was to qualify the capsule structure and afterbody heat protection. The Atlas guidance system had been programmed to cause the capsule to enter the atmosphere along a trajectory that would cause maximum afterbody heating, and maximum entry deceleration. The test called for a 20-minute, 1,500-mile ballistic flight to an altitude of 110 miles.

Although the malfunction caused the capsule to separate from the Atlas, the capsule remained intact until it struck the water. Because of the flight objectives, an escape rocket and emergency parachute sequence were not incorporated.

Telemetry was received from the capsule from launch until impact for a total of three and one-half minutes. At the time of the unexplained explosion, the Atlas was traveling 1,000 mph at an altitude of six miles southeast of the launch pad. Thirty-six hours after launch, salvage crews had recovered nearly all the capsule plus the Atlas engines from 50 feet of water.

Telemetry received during the flight, and data on tapes recovered from the capsule, indicated that the abort sensors -- which would have triggered the escape system had it been installed on this flight -- signaled just before the powered flight ended.

Capsule Modifications Continue

Wind tunnel and flight tests of the capsule have demonstrated that aerodynamic heating and air stresses or "loads," during powered flight may prove more severe than

was originally anticipated. As a result, the capsule structure has been strengthened to withstand the pressures resulting from the opening of the drogue parachute. The capsule escape tower structure has been strengthened and the electrical conduits have been modified to provide extra protection against heat. Methods of increasing cabin pressure are being examined to prevent excessive stresses resulting from an abort maneuver.

In addition, beryllium has been substituted for a cobalt alloy in the afterbody section that houses the capsule's main parachute, and the entire afterbody skin has been thickened. These two measures were taken as a result of the Big Joe flight of September 9, 1959, which indicated a peak temperature of 2,300 degrees Fahrenheit on the afterbody.

Astronaut Training Moves Ahead

During the report period, the seven Mercury astronauts experienced a wide range of training -- from survival tests in the Nevada desert to dynamic mission simulations in human centrifuges. They acquired many hours in a number of training devices that simulate capsule environment and space flight.

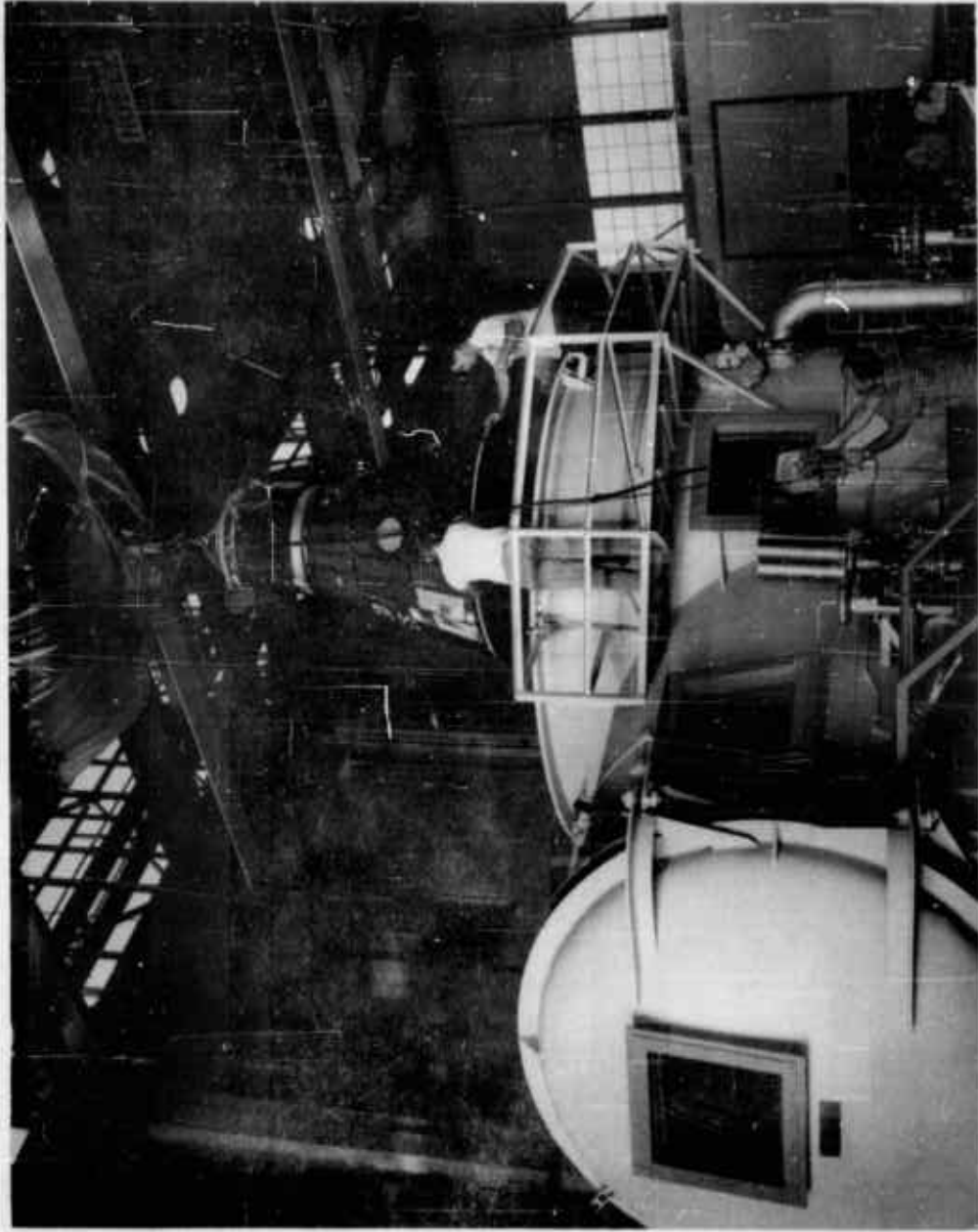
Two "Manned Satellite Procedures Trainers" were delivered to NASA by McDonnell Aircraft Co. -- one to Langley in May, the other to Cape Canaveral in July -- and the astronauts began training in them.

The trainer, designed to simulate realistically both Redstone ballistic and Atlas orbital missions, consists of a mockup of the Mercury capsule cockpit as well as the instructor's console and an analog computer and power supply.

Most of the trainer controls and indicators are fully operational and duplicate the feel and motion of the flight capsule and controls. The trainer capsule is mounted on a dolly and can be tilted through an angle of 70 degrees.

In connection with the capsule trainer exercises, the astronauts have engaged in extensive review of the major capsule subsystems with NASA and contractor technical personnel.

In mid-July the astronauts took part in a one-week course in desert survival, conducted by the USAF Training Command Survival School, Stead AFB, Nev.



A mercury capsule is lowered into an altitude chamber for testing

In June and August, the astronauts practiced escape from the capsule at sea off Pensacola, Fla. Escape procedures involve removing the restraining harness, unshackling two oxygen hoses, disconnecting helmet radio leads, removing pins from the instrument panel to push it aside, and opening the pressure hatch at the top of the capsule. The astronaut must then eject an empty parachute can and pull himself upward through the 16- by 32-inch opening as the capsule bobs up and down on the waves.

They took a brief course in star identification and celestial navigation in April and participated in zero-gravity familiarization flights in the KC-135 at Wright Patterson AFB during September.

In April and again in October, the astronauts went through intensive training in the centrifuge at the Navy Medical Acceleration Laboratory, Johnsville, Pa. Wearing their pressure suits in the centrifuge capsule for the first time in the April sessions, they were subjected to a low pressure environment simulating an actual Mercury sub-orbital flight.

In the October 3 - October 21 training period, simulation of the suborbital Redstone mission was made as realistic as possible, utilizing most of the major ground support equipment. This included a trailer truck equipped with pressure suits, bio-instrumentation checkout consoles, etc., which the astronaut will occupy for about one hour and a half before an actual launch.

The centrifuge, a two-gimbaled gondola on a 50-foot arm, can provide acceleration pressures to 40 g. Each astronaut has experienced up to 16 g, the highest possible g load that can be encountered on a Mercury flight. During each three-hour session in the gondola, the astronaut was subjected to five 15-minute dynamic (twisting, revolving) runs involving simulated acceleration forces, and three static runs during which the centrifuge was not operated but the pilot "flew" by his instruments, which were driven by an analog computer.

Throughout each simulated flight, quantities of medical data were telemetered from the dynamic speeding gondola to the medical monitoring consoles. Specific objectives of the centrifuge program include: training and familiarizing the pilot with the Redstone mission and evaluation of the astronauts' personal gear such as restraint harness, flight couch, pressure suit, bio-sensors, and communications equipment.

Provisions were made in the centrifuge gondola circuit to simulate a failure of the Mercury capsule's automatic stabilization and control system, allowing the astronaut to practice taking over manned control as he will be able to do in actual flight.

In October, a McDonnell-built "Environmental Systems Control Trainer" was delivered to the Navy Aircrew Equipment Laboratory in Philadelphia, Pa. The astronauts are scheduled to start exercises with the trainer in January. The trainer consists of a capsule body with only the environmental control system installed.

During November and in the immediate months thereafter, the astronauts will be assigned to various phases of the unmanned ballistic flight program leading to the first manned suborbital flight early next year.

MERCURY TRACKING AND COMMUNICATIONS SYSTEM IS READIED

In early 1961, the worldwide Mercury Tracking and Ground Instrumentation Network will become operational, in readiness for the first unmanned orbital abort tests scheduled for the second quarter. The Bermuda station, vital to trajectory calculations immediately after Atlas shutdown, is near completion. The stations participating in the upcoming manned, suborbital Redstone flights down the Atlantic Missile Range were ready.

All equipment for the Cape Canaveral and Grand Bahama and Grand Turk island stations has been delivered. Construction began at Kano, Nigeria, and Guaymas, Mexico; work moved forward at Grand Canary Island; Zanzibar; Point Arguello, Calif.; and Corpus Christi, Texas. Construction at Kauai Island, Hawaii, was accelerated during the report period.

Installation of communications and telemetry equipment for the ship stations that will operate in the Atlantic and Indian Oceans progressed satisfactorily.

Network Stresses Reliability and Speed

The network has been designed to provide nearly continuous ground control and monitoring of manned suborbital and orbital flights from lift-off to landing. The stations are being equipped with two types of radar as well as equipment to provide telemetry, command control, and voice communications coverage during a five-hour, three-orbit mission.



The Mercury Control Central Facility, Cape Canaveral, Fla., monitors a simulated Mercury capsule shot.

In preparing the network, NASA has concentrated on reliability and the speediest possible data processing and transmission system. The spacing of the network stations is such that the capsule will be in nearly continuous radio contact with the ground.

MERCURY MEDICAL TEAM ORGANIZED

A team of 160 military and civilian medical specialists has been organized to serve with Project Mercury's recovery and tracking forces. Of these, 150 will stand by at hospitals near high- and low-probability landing areas, e.g., Cape Canaveral, Puerto Rico, etc., to check the astronaut after flight. The balance will team with engineers at six tracking stations (Cape Canaveral; Bermuda; Muchea, Australia; Hawaii; Point Arguello, Calif.; and Guaymas, Mexico) to monitor the capsule's environmental control system and the astronaut's physical condition.

The recovery group will be stationed at hospital facilities at Cape Canaveral, Grand Turk, Grand Bahamas, Bermuda, and the Canary Islands, and on several recovery ships. The high-probability landing areas are off Cape Canaveral (in case of a launch abort); the Canary Islands (if capsule fails to achieve orbit); and Puerto Rico (the planned orbital landing area).

RECOVERY SUPPORT

The Department of Defense recovery support for Project Mercury is under the direction of the Commander of Destroyer Flotilla 4 at Norfolk, Va. The recovery forces include naval vessels, aircraft, helicopters and amphibious rescue craft. These forces will be deployed in the Atlas, Redstone, and Little Joe landing areas, along the Atlas launch path, and at the end of the first and second orbits.

As the capsule is lowered to the surface of the ocean, location aids such as SOFAR bombs will be ejected and direction-finding radio signals will be sent out to aid in rapid location of the capsule. Ships and aircraft in the planned recovery area will then home on the direction finding signals. Aircraft will guide surface vessels to the scene of capsule impact and the surface vessels will then recover the capsule from the ocean and carry it to shore.

As in the case of a manned aircraft with ejection seats and pilot parachutes, provision must be made for unplanned emergencies. First, a separate rocket propulsion system,

called an escape or abort system, is provided. This must carry the capsule to safety, should the Atlas malfunction while on the launch pad or during the early phases of ascent. Depending on where and under what conditions the emergency occurs, the abort system may be energized automatically or by ground control, or by the astronaut himself.

Should an abort or emergency landing be necessary, the capsule will land in other than the planned recovery area and provisions must be made for retrieval of the capsule therefrom. If the emergency should occur while the capsule and launch vehicle are on the launch pad, the capsule, after firing the escape rocket system, would land within a short distance of the launch pad, and emergency recovery provisions can readily be implemented. Should an emergency condition occur fairly early in the flight while the vehicle is well below orbital velocity, the capsule would land in the area between Florida and Bermuda. This area will be covered with aircraft and surface vessels for possible emergency recovery purposes. If an abort should be required at near-orbital velocity, the capsule could land anywhere over a substantial portion of the earth's surface unless some corrective action is taken. Under such circumstances, the retro-rockets of the capsule will be utilized to control the emergency landing point to within one of several planned landing areas in the Atlantic Ocean. These recovery areas will be thoroughly patrolled by aircraft and surface vessels. Recovery forces will also be provided within the landing area that would be reached by ending orbital flight after the first or second orbits.

CHIMPANZEES READIED FOR FLIGHT

A group of young chimpanzees is undergoing training at Holloman Air Force Base, N.M., for flights in the Mercury capsule preceding the manned flights. The chimpanzees will exercise the Life Support System and their psychomotor task performance will be recorded.

SPACE TASK GROUP MANAGES PROJECT MERCURY

Responsibility for management of Project Mercury is as follows:

The NASA Space Task Group has over-all systems management responsibility. The Space Task Group drew up the Mercury capsule specifications upon which the contractor capsule proposals were made. (The capsule contract was

awarded to McDonnell on February 6, 1959.) Launch vehicles for preliminary flight tests and orbital flights were negotiated directly by NASA.

Range network specifications were established by the Space Task Group and the Langley Research Center. (The Western Electric Co. was selected as network contractor on July 13, 1959.) Capsule recovery will be a joint NASA-Department of Defense effort.

NASA is making maximum use of its own research facilities and those of contractors for various phases of Project Mercury. For example, wind tunnels at NASA's Langley, Lewis, Ames, and Marshall Centers, at the USAF facility, Tullahoma, Tenn., and at the McDonnell plant, St. Louis, Mo., are being employed to obtain data for several different capsule escape and launch vehicle configurations.

Scientific Satellites and Sounding Rockets

PROGRAM DESCRIPTION

Of basic importance to NASA activities are studies of the earth and its environment (geophysics), and of the sun, stars, and universe (astronomy). These investigations are conducted under the agency's scientific satellite* and sounding rocket programs. In geophysics, research is focused on the atmosphere and ionosphere, and on energetic particles. (These are atomic particles moving at very high speeds and thus possessing great amounts of energy. They include the particles forming the Great Radiation Region surrounding the earth, cosmic rays, and the particles involved in auroras.)

GEOPHYSICAL SOUNDING ROCKET EXPERIMENTS

Generally speaking, sounding rockets are designed to attain altitudes of no more than 4,000 miles, while rocket vehicles powerful enough to penetrate farther into space are termed probes. Small rockets, such as those used for scientific studies during the International Geophysical Year and afterwards, are employed for sounding to altitudes of 150 miles. One- or two-stage vehicles, they are usually Aerobees, Nike-Cajuns, or Nike-Asps. (Goals of the sounding rocket program were detailed in NASA's Third Semiannual Report to Congress.)

During the report period, NASA successfully launched 15 sounding rockets carrying scientific experiments. Most were fired from Wallops Station, Va.

Aerobee Probes Atmosphere Composition and Pressure

On April 29, an Aerobee rocket carried instruments for determining the composition and pressure of the atmosphere to an altitude of 154 miles. Mass and ion spectrometers

* During the report period, no scientific earth satellites were launched.

functioned well and the telemetered data were of excellent quality. Detailed analyses of the instrumental findings are under way. The information must be correlated with vehicle-trajectory data before firm conclusions can be drawn on how the composition of the atmosphere varies with altitude. The experiment was performed by Goddard Space Flight Center.

Nike-Asp Investigates Winds in Upper Atmosphere

On May 24, a Nike-Asp rocket carried a payload that released a trail of sodium vapor from an altitude of about 50 miles to 120 miles. Results of the sodium-vapor experiment -- a continuation of a program that began nearly a year earlier -- indicated that there are regions of intense turbulence and strong wind shears below an altitude of about 60 miles. Above, the wind rapidly carried the trail streaming to the north. The experiment was performed by the Geophysics Corporation of America, Bedford, Mass., under NASA contract.

Nike-Cajun Grenade Experiment

On July 8 and 13, Nike-Cajun rockets carrying grenades, timed to explode at intervals during flight, were fired to altitudes of 65 and 38 miles, respectively. A network of ground stations photographed the grenade flashes and precisely timed the arrival of the resulting sound waves. From these measurements it is possible to determine atmospheric temperatures. Since winds affect the time the sound takes to reach the ground, wind direction and velocity at various altitudes can also be estimated by the grenade technique. Much computing is required for analyzing the data from these launchings; final results will not be known for some time to come. The grenade experiments were the first in a series which Goddard Space Flight Center is conducting to learn more about winds and temperatures between altitudes of 25 and 75 miles.

Aerobee Cloud-Cover Experiments

On September 15 and 24, two small Aerobee rockets were launched, carrying cameras to photograph cloud cover and other weather phenomena. The payloads were recovered, and the cameras and film were returned to Goddard for data analysis.

Aerobee Ionosphere Investigations

Two Aerobee rockets, launched to investigate the ionosphere, used ejectable payloads to obtain measurements that would not be influenced by the vehicles themselves. On June 15, the first experiment recorded useful information although the vehicle attained only about 80 percent of its predicted altitude. Preliminary results from data analysis indicate that higher ion densities and lower electron temperatures (a measure of the thermal or heat energy of the electrons) were found during the second experiment than during the first. Further experiments will be needed to determine the reasons for these differences. The experiments were conducted by the University of Michigan under a NASA contract.

SBE Launchings

Three launchings were made in the Solar Beam Experiment (SBE) Program, which was described briefly in NASA's Third Semiannual Report to Congress. An important part of the SBE payload is a package of special emulsion film that is very sensitive to cosmic rays and other energetic particles. The film must be processed after exposure to develop the identifying tracks made by the particles. Hence, the payload must be recovered after the experiment. Provisions were made to separate the payload package from the rocket at the proper time and to parachute it slowly to earth. The payload also contained a small radio beacon to assist in tracking and locating it after landing.

The first SBE launching on June 6 had the dual objectives of testing the payload recovery system and of monitoring background radiation from the sun during normal, or quiet, periods of solar activity. The rocket attained an altitude of 68 miles. The payload was recovered intact and all objectives of the test were met. Results of the experiment will be used in analyzing two additional SBE payloads that were launched into solar particle streams September 3 and 20. Payloads of all three SBE experiments were sent to Goddard Space Flight Center which manages the program.

NERV Experiments Begin

Closely related to the Solar Beam Experiments is the NERV (Nuclear Emulsion Recovery Vehicle) program, designed to study energetic particles in the lower belt of the Great Radiation Region.

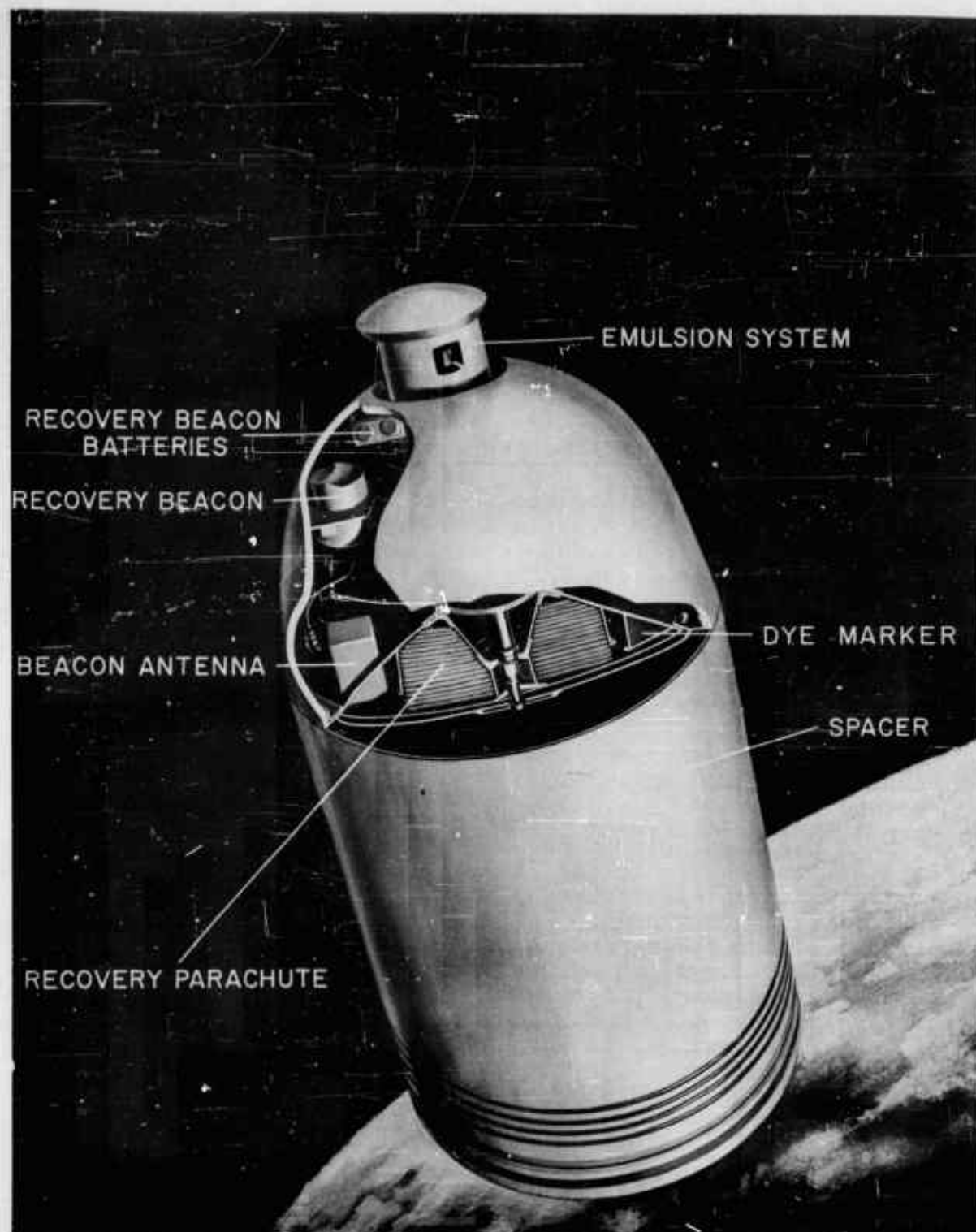
At 11:35 a.m., EDT, September 19, NASA launched the first NERV experiment from Point Arguello, Calif. An unguided, four-stage Argo D-8 sounding rocket fired an 83.6-pound capsule to an altitude of 1,260 miles. The bell-shaped capsule, 16 inches long and 19 inches in diameter, arced south over the Pacific, and parachuted to a landing in the ocean about 1,300 miles from Point Arguello at 12:03 p.m., EDT. A recovery ship retrieved it at 2:26 p.m., EDT. NASA utilized PMR so that NERV could be fired south to coincide with the magnetic lines of force that govern movement of particles in the Great Radiation Region. This was NASA's first launching from PMR and the first flight of the Argo D-8.

NERV Payload Description -- The primary payload, consisting of 25 wafers of nuclear emulsion (a photographic film extremely sensitive to charged particles), rotates within a cylindrical tungsten shield. The shield contains a small port which admits ionizing particles. The emulsion records particles with energies as low as 5 MEV (million electron volts), providing a substantially broader range than radiation-measurement devices such as Geiger counters. The tungsten cylinder is extended from the nose of NERV soon after launching (at about 300 miles altitude) and retracted at an approximate altitude of 600 miles, before entry into the atmosphere.

Argo D-8 -- Argo D-8 is a solid-propellant sounding rocket, having a Sergeant assisted by two Recruit auxiliary rockets as first stage; Lance rockets as second and third stages, and an Altair rocket as fourth stage. It is 62 feet long and weighs more than 13,000 pounds.

Mold Spore Experiment -- In addition to the nuclear emulsion experiment, the forepart of the NERV capsule contained three cultures of neurospora (spores of the common bread mold), one-celled organisms characterized by swift asexual reproduction. University of Florida biologists will study the recovered spores to correlate mutations with the radiation intensities recorded by nuclear emulsion.

Two Aspects of Radiation Study -- The nuclear emulsion was returned to the Goddard Space Flight Center (which managed the experiment) where it was developed and is being studied. Analysis of the emulsion will assist in evaluating the theory that some of the particles in the lower belt of the Great Radiation Region are products of neutron decay caused by interaction of cosmic rays with nuclei of the earth's upper atmosphere. Other theories relating to interaction of the radiation region with the earth's atmosphere and magnetic field will also be appraised.



Partial cutaway of the Nuclear Emulsion Recovery Vehicle (NERV) with cylinder containing the emulsion film extended as it was during the most of the flight.

The nuclear emulsion method provides detailed data on the number, charge, mass, velocity, and direction of charged particles over a given geographic area. For the first time, the radiation that will be encountered can be measured precisely and thus minimum shielding for manned spacecraft can be determined.

Prime Contractors -- The prime contractor for the NERV vehicle was the Missile and Space Vehicle Department of General Electric Co., Philadelphia, Pa. The nuclear emulsion was manufactured by Ilford Ltd., London, England. The prime contractor for the launch vehicle was Aerolab Development Corp., Pasadena, Calif.

Aerobee Measures Upper Atmosphere Neutrons

On August 23, an Aerobee rocket, reaching an altitude of 120 miles, carried a payload to measure the intensity of neutrons in the upper atmosphere. Neutrons are related to the interactions of cosmic rays and energetic particles with the earth's atmosphere. The payload functioned properly and useful data were acquired during 7 minutes, 30 seconds of flight. The experiment was designed, built, and conducted by New York University and monitored by Goddard Space Flight Center. The data is being analyzed by New York University.

Nike-Asp Delays

The schedule of launchings based on use of Nike-Asp rockets has been delayed because of engineering difficulties with the vehicle. Several launches failed in late spring when vehicles broke up shortly after second-stage ignition. A study of the failures, plus X-ray examination of some second-stage rockets on hand, indicated to NASA that the trouble might be due to the porous grain structure of the second-stage propellant. On August 9, an engine containing suspected propellant was flight tested. The second stage exploded and broke up shortly after ignition. Later, another rocket, which was powered by propellant that X-ray examination had shown to be sound, broke up in the same way.

All NASA Nike-Asp launches have been called off until a detailed engineering study can be finished. The entire vehicle is being examined by experts from the Goddard and Langley Research Centers. Every factor will be carefully investigated, including aerodynamic stability, aerodynamic heating, structural considerations, and vibrational effects.

Until the recent trouble, the Nike-Asp configuration had established a record of only one explosive failure out of every nine rockets fired. Approximately 52 Nike-Asps have been launched since 1957.

ASTRONOMICAL SOUNDING ROCKET EXPERIMENTS

Aerobee Ultraviolet Experiments

During the report period, three Aerobee rockets were launched for astronomical studies of ultraviolet radiation from the stars and nebulae.

The first flight was on April 26. Reaching an altitude of 113 miles, it yielded excellent data on ultraviolet radiation of stellar origin in the wavelength region of 2,200 to 2,700 angstroms.* High humidity before launch affected some of the sensitive electronic circuits. This caused one of the experiments, a 1,300-angstrom ultraviolet detector, to malfunction so that it obtained no scientific data.

On May 27, a second Aerobee rocket reached an altitude of 135 miles but developed a high roll-rate during its climb. Although this impaired the quality of the data, the flight yielded good measurements of ultraviolet radiation resulting from chemical reactions in the outer atmosphere.

On June 24, the third Aerobee recorded excellent data on ultraviolet radiation from the stars. The 1,300-angstrom ultraviolet detection equipment worked well. In addition to measuring stellar sources of ultraviolet radiation, the experiment furnished information on distribution of ozone in the upper atmosphere at night.

The three Aerobee experiments were conducted by Goddard scientists who are now analyzing the data in detail.

* A unit employed to indicate wavelengths of visible, ultraviolet, and X-ray radiation. About 250 angstroms equal one-millionth of an inch.

PROGRESS ON SCHEDULED SATELLITES

The primary aim of NASA's scientific earth-satellite and sounding rocket program is to increase knowledge of the upper atmosphere and space. Satellites and sounding rockets are the tools that enable the research scientist to transport his equipment to altitudes far above the ceilings of balloons and aircraft and thus to measure directly the atmosphere and the environment of outer space. The ability to make observations from above the obscuring and distorting effects of the earth's atmosphere has opened a new and still comparatively unexplored field to astronomy.

The first step in these experiments is to investigate physical phenomena and their magnitudes on a broad scale. Once scientists have an approximate idea of the nature and extent of a phenomenon, they can devise experiments for more exact and detailed measuring. When geophysical phenomena are being studied, repeated observations are usually necessary over long periods of time to gain knowledge of variations from day to night and with the changing seasons. Much time is also required to correlate observations with changing solar activity and other phenomena.

GEOPHYSICAL SATELLITES

Atmospheric Structure Satellite

Goddard Space Flight Center is designing and developing this satellite to measure the density, composition, pressure, and temperature of the earth's atmosphere from altitudes of 150 to 700 miles. It will be the first NASA satellite for studying the upper reaches of the atmosphere in detail. The variation of these properties with the time of day and with latitude will be measured during the satellite's useful lifetime, expected to be about one year.

A sphere with a diameter of 35 inches, the payload will weigh about 400 pounds and will be launched by a Thor-Delta vehicle. Among major experiments planned are: 1) two double-focusing mass spectrometers to measure neutral molecules of molecular weight 1 through 28; 2) two Bayard-Alpert hot cathode total pressure gages to determine atmospheric pressure to about one hundredth of a trillionth of an atmosphere; and 3) two Redhead cold-cathode total-pressure ionization gages of even greater sensitivity.

The two mass spectrometers are being fabricated by the Consolidated Systems Corporation, Monrovia, Calif. Goddard has received samples of the Bayard-Alpert gages (Westinghouse) and the Redhead gages (NRC Equipment Corporation, Newton Highlands, Mass.) and is testing them. In June 1960, NASA awarded a \$159,894 contract for fabrication of the satellite shells to the Budd Company, Philadelphia, Pa. As the report period ended, over-all telemetry design was nearly completed and construction of telemetry equipment had started.

Micrometeoroid Satellite

Most of this payload will be made up of different types of detectors for measuring micrometeoroids in space so that scientists can determine whether these high-velocity grains of cosmic matter will be hazardous to spaceflight. Auxiliary instruments will measure micrometeoroid temperatures and acceleration.

Langley Research Center is developing a micrometeoroid experiment comprising 160 pressurized cylinders, divided into four groups, each group made of a different thickness of metal. Penetration of a cylinder wall by a micrometeoroid will be indicated by a telemetered signal reporting the escape of the pressurizing gas.

Another micrometeoroid experiment, designed by Lewis Research Center, consists of a series of sensors protected by varying thickness of stainless steel. The sensors are very fine gold grids deposited on a plastic film base. If a micrometeoroid should penetrate a steel plate, it would break the delicate gold grid; this, in turn, would signal the break and identify the plate.

Sensors developed by Goddard Space Flight Center and consisting of cards wound with layers of very fine wires will be installed in the satellite. Each card has a detecting area of about seven square inches. Wire breaks by micrometeoroids will be reported by the telemetry system. Among other detectors furnished by Goddard will be sensitive microphones that can record and signal repeated micrometeoroid impacts or densities during the entire active life of the satellite. The satellite will be launched by a Scout vehicle into an orbit having a planned perigee of about 320 miles and an apogee of about 850 miles. Total weight of the satellite in orbit will be approximately 163 pounds, with the scientific payload accounting for 112 pounds of it.

Detectors for a prototype payload are being tested and evaluated at NASA research centers, as are satellite components. At the end of September, the payload was about to undergo tests in a Langley high-altitude simulator where various extreme conditions in space can be approximated. Development of the telemetry system is on schedule and arrangements for data handling are in process.

Air Density-Drag Measurements Satellite

The prime object of this NASA experiment is to determine upper atmospheric densities by measuring the air drag on a lightweight satellite. An inflatable plastic sphere, 12 feet in diameter and weighing 14 pounds, the satellite will be measurably affected by air drag in an orbit planned to have a perigee of about 450 miles and an apogee of 1,200 miles.

The payload will be tested on the first orbital flight of the Scout launch vehicle -- in which, however, vehicle performance is the principal consideration.

Langley is directing the project and fabricating and integrating the payload. Plans and arrangements for tracking are well along. Goddard will be responsible for beacon tracking. The Smithsonian Astrophysical Observatory will track the satellite optically. NASA awarded an \$80,000 contract to the Astro-Electronics Products Division of the Radio Corporation of America, Princeton, New Jersey, for the radio beacons with which the satellite will be equipped.

The air density-drag measurements satellite should have approximately one year of useful life.

Ionosphere Direct Measurements Satellite

Time and space distribution of electrons and ions in the ionosphere will be investigated by this NASA satellite. It will also be equipped to study micrometeoroid impacts and momentum. The satellite will be launched by a Juno II vehicle from AMR. The orbit is planned to have a 200-mile perigee and an 800-mile apogee. Weighing 85 pounds and measuring 30 inches in height and diameter, the satellite will be formed of two truncated cones joined at their bases.

Experiments will include a radio-frequency impedance probe, two single-grid and two multiple-grid ion traps, and two Langmuir probes as well as an electric field meter to

measure vehicle potential.* The payload will also include micrometeoroid detectors and a solar sensor to determine the satellite's orientation.

Goddard is in charge of payload instrumentation and data acquisition and reduction. Marshall Space Flight Center is responsible for the satellite housing, antennas, power supply, fabrication, and environmental testing. The flight models are being built there. The antenna release mechanism and other specialized antenna equipment have been tested as separate components. Recently, when NASA surveyed the data acquisition coverage scheduled for the Minitrack network, it was found that four stations required improved antennas. These have been ordered from the All Product Co., Mineral Wells, Texas.

Ionosphere Beacon Satellite

This satellite is designed to determine electron distribution throughout the ionosphere to the maximum altitude of the satellite, and to determine the structure and transmission characteristics of the ionosphere as it applies to radio communications.

The payload will be launched by a Juno II vehicle from AMR into an orbit having a perigee of approximately 250 miles and an apogee of about 1,600 miles. The payload consists of electronic equipment to transmit six harmonically related radio signals simultaneously. Depending on their frequencies, the signals will be affected to varying degrees during their travels through the ionosphere.

Goddard Space Flight Center is responsible for scientific direction of the experiment, and for tracking and orbital predictions. Marshall Space Flight Center is charged with payload design engineering along with integration of the satellite and launch vehicle. A network of specially instrumented receiving stations that were engaged in similar -- but somewhat less comprehensive -- ionosphere studies during the International Geophysical Year will be the main element for data acquisition and analysis. The

* Spacecraft accumulate charges from the ionosphere and from the ultraviolet radiation of the sun. This charge, or potential, must be known in order to interpret the results of many NASA experiments.

network includes stations of the University of Illinois; Stanford University; Pennsylvania State University; and the Central Radio Propagation Laboratory of the National Bureau of Standards, Boulder, Colo.

Payload and antenna design have been completed and the prototype payload has been subjected to initial tests which disclosed minor mechanical and electronic weak points. These have been corrected. The mechanism for erecting the antenna has also been redesigned. Environmental and electrical prototypes of the satellite have been constructed, and began undergoing tests in September.

Swept-Frequency Topside Sounder

A joint Canada-U.S. Project, this satellite will examine the structure of the ionosphere from above by a technique of radio-echo sounding hitherto possible only from the ground. For decades the ionosphere has been studied by beaming radio signals to the lower portion of the ionosphere (of high-electron density) which reflects them back to the ground. Thus frequencies, such as those used for ordinary commercial radio, cannot penetrate the ionosphere although radar, FM, and TV signals do so readily. The swept-frequency topside sounder satellite experiment will be the first attempt to apply the radio-echo technique to the upper portions of the ionosphere -- at altitudes of between 188 and 250 miles -- from above. The orbit planned for the satellite will have a perigee of about 600 miles and an apogee of about 1,000 miles.

As noted, the satellite is a cooperative effort of the Canadian and United States Governments. The payload is being built by the Canadians at no cost to the U.S. The U.S. will furnish the Thor-Agena launching vehicle. Both nations will operate data acquisition centers; the data will be shared by all participating scientists.

The payload is being built by the Defence Research Telecommunications Establishment of Canada. Goddard is responsible for project coordination, payload integration and testing, and for U.S. tracking and telemetry.

Work on the Canadian payload is in progress. A launch vehicle has been assigned by the U.S. from the Thor-Agena B series.

Fixed Frequency Topside Sounder

This U.S. satellite will have much the same mission as the swept-frequency topside sounder. However, the technique employed is significantly different. The satellite will sound the ionosphere at six radio frequencies between 2 and 15 mc. The Canadian satellite will continuously sweep the measuring frequency over the entire 2- to 15-mc range. The U.S. experiment will rapidly make approximate determinations. The Canadian experiment will obtain more precise data at a slow rate.

NASA plans for this satellite a nearly circular orbit, with an altitude of about 600 miles. A Scout launching vehicle will be used.

Goddard is managing the project. The Central Radio Propagation Laboratory of the National Bureau of Standards has over-all scientific responsibility for the payload and the experiment, including design and consulting services, performance of the experiment, and data processing. The Airborne Instruments Laboratory, a division of Cutler-Hammer Inc., Deer Park, Long Island, N.Y., was awarded a NASA contract to design and develop payload electronics and ground station equipment.

Design studies of the payload are under way. Plans are being drawn for using sounding rockets in tests to assure that the complex electronic gear will function properly under spaceflight conditions and will be reliable over an operating lifetime of about one year.

Electron Density Profile Probe

This experiment will measure electron density under normal ionospheric conditions and will investigate radio transmission to the ground from the maximum altitude (more than 6,000 miles) planned for the Scout launch vehicle. Two methods will be used to measure electron density in relation to altitude. In one, radio signals sent from the vehicle will be analyzed for effects caused by their passage through the ionosphere. The other method will determine characteristics of the ionosphere from the electrical effect it produces on special radio antennae carried by the payload. The payload will weigh 100 pounds.

Goddard is responsible for scientific management, payload engineering and integration, tracking, telemetry, and data processing. The antenna system is being built by Sulzer Laboratories, Inc., Washington, D. C. New Mexico

State University is developing special radio facilities for the ground station. Goddard is building the payload instrumentation. The airborne transmitter prototype, and prototype equipment for the ground station, are undergoing evaluation tests. As the report period ended, construction of flight payloads to be tested in Javelin sounding rockets was about 90 percent completed. After these tests, the flight payload will be constructed.

International Ionosphere Satellite (U.K. No. 1)

This will be the first satellite in the NASA international program under which experiments and payloads prepared by foreign scientists are to be carried in U.S. vehicles. Experiments were selected by scientists of the United Kingdom in consultation with NASA scientists. U.K. scientists are building the experiments. They will also be responsible for data analysis. Goddard will design, fabricate, and test the prototype and flight models.

The U.K. satellite will carry a Langmuir probe to study electron temperatures and concentrations in the ionosphere and instruments to determine electron densities in the vicinity of the satellite, to measure solar radiation and correlate it with ionospheric phenomena, and to observe primary cosmic rays and study their interactions with the earth's magnetic field. The payload will weigh about 170 pounds. The orbit planned for the satellite will have a 200-mile perigee and a 600-mile apogee. A Scout launching vehicle will be used.

International Program Satellite (No. 2)

NASA has allocated a Scout vehicle to launch the second satellite in the international program series. It will probably be launched a year after the first. Selection of the experiments is being discussed by NASA and British scientists.

Energetic Particles Satellite

This NASA satellite will measure numbers, types, and energies of the particles making up the Great Radiation Region in relation to location, time, and direction of the particles. It will also study variations in primary cosmic ray intensity over an extended period of time. The satellite should have an operating lifetime of about one year.

Ten different energetic particle-detecting systems and a magnetometer will make up the main part of the scientific instrumentation. A photocell optical sensing system will be used to furnish knowledge of the satellite's orientation. The orbit will encompass as large a region of space surrounding the earth as the capability of the vehicle will permit -- a perigee of approximately 150 miles and an apogee of about 40,000 miles. A Thor-Delta launch vehicle will be used.

The payload is being built by Goddard Space Flight Center. Experiments will be contributed by the State University of Iowa, the University of New Hampshire, Ames Research Center, and Goddard. Antenna development has been undertaken by New Mexico State University. Goddard is responsible for data acquisition and reduction.

By the close of the report period, basic design of the satellite had become firm and payload electronics were being constructed, evaluated, and tested. Particular attention is being paid to problems associated with the silver-cadmium battery power pack. Spectra Laboratories, Inc., North Hollywood, Calif., is fabricating the solar paddlewheels under NASA contract.

Recoverable Nuclear Emulsions Probe

NASA is studying the feasibility of using a Scout vehicle -- with a recoverable payload -- as a very high-altitude probe for obtaining a detailed study of the Great Radiation Region by means of nuclear emulsions. Nuclear emulsions are ideally suited for detailed studies of a radiation field and for assessing its hazard to life.

Goddard Space Flight Center will manage the experiment, which is part of the Nuclear Emulsion Recovery Vehicle (NERV) program (see p. 37).

NASA has asked General Electric Co., Philadelphia, Pa., contractor for the NERV program, to submit a proposal for the experiment, including modification of a Scout vehicle to carry it.

Orbiting Geophysical Observatory

These will be the first satellites developed under a new concept and approach. Heretofore, U.S. satellites have, in effect, been "custom-designed," including supporting power supplies, telemetry, hardware, and basic structures for each particular mission and scientific payload.

For early and comparatively light and simple payloads, this procedure was dictated by the variety of launching vehicles employed and by the embryonic state of space science and technology. During the next few years, however, use of the Atlas-Agena B and Thor-Agena B launching vehicles will make far larger satellites possible. To custom-design the heavy and complex scientific satellites that these launch vehicles will make possible would be prohibitive both in expense and in lead times. Moreover, to take full advantage of rapid advances in the space sciences, there is urgent need to reduce lead time for incorporating improved and new instruments into payload structures.

Guided by these considerations, NASA plans to have ready for the larger, more powerful launch vehicles a standard satellite structure, complete with power supply, telemetry, data storage facilities, and other basic equipment. Provisions will be made for accommodating a larger number of experiments (perhaps as many as 25) which could be inserted into compartments and connected to the electrical power and telemetry equipment. Each unit would be a module, a simple plugged-in electronic "building block." Thus, satellite structures could be fabricated quite independently of the scientific experiments. Obviously, this approach will save both time and money.

By August 1960, planning and preliminary design studies had advanced far enough for NASA to hold a bidders' conference at Goddard Space Flight Center (See Chapter 17, pp. 204). Representatives of 17 companies were briefed on the concept and objectives of the geophysical observatories and received design specifications.

The first geophysical satellite will be launched by an Atlas-Agena B into a highly eccentric orbit having an apogee of about 70,000 miles and a perigee of 175 miles. Termed the Eccentric Orbiting Geophysical Observatory, its main purpose is to study energetic particles and other geophysical phenomena requiring the extensive orbit selected.

Nine months or so after the eccentric orbiting observatory has been launched, a Thor-Agena B will be used for a Polar Orbiting Geophysical satellite. It will go into a relatively low polar orbit, having a perigee of about 175 miles and an apogee of about 700 miles. It will be instrumented chiefly to study the atmosphere and ionosphere, with particular attention to the unexplored regions of the atmosphere above the poles.

PRINCIPAL ASTRONOMICAL PROJECTS

NASA astronomical investigations are concentrated on three major areas: 1) galactic astronomy; 2) solar physics; and 3) astrophysics. The agency has begun construction of satellites for experiments in galactic astronomy and solar physics. The astrophysics program is concerned with geodetic investigations, relativity investigations, and radio astronomy projects. In these areas preliminary experiments and planning studies are in progress and research contracts have been let to lay the foundation for advanced satellites and probes to come. Substantial progress has been made on the following astronomical satellites:

Gamma Ray Astronomy Satellite

This satellite is designed to detect and map the distribution of high energy gamma rays in space beyond the earth's atmosphere, and to relate the measurements to variations in cosmic ray density and to the density of interstellar matter throughout our galaxy. Gamma rays are high-energy radiation of very short wavelength. They are associated with the interaction of cosmic rays, or other energetic particles, with matter.

The principal measuring apparatus consists of a gamma ray "telescope," made up of ultra-sensitive detectors. The satellite will be stabilized to rotate about a selected axis. Photocells will be used to determine orientation; this information, combined with the directional measurements of the gamma ray telescope, will permit mapping of the distribution in space of extraterrestrial gamma rays.

The satellite will be launched into an eccentric orbit below the Great Radiation Region. It will have a perigee of about 200 miles and an apogee of about 500 miles. A Juno II vehicle will be used.

The project is under the management of Goddard Space Flight Center. Scientific instrumentation is being furnished by the Massachusetts Institute of Technology, Cambridge, Mass. Marshall Space Flight Center is in charge of command and communications equipment, payload integration, and satellite construction. Prototype instrumentation has been completed and sent to Marshall for use in satellite construction work and tests. Payload electronic equipment is being constructed and tested, and working models of a special tape recorder are being evaluated. The data analysis system is in the final stages of design.

Orbiting Astronomical Observatory

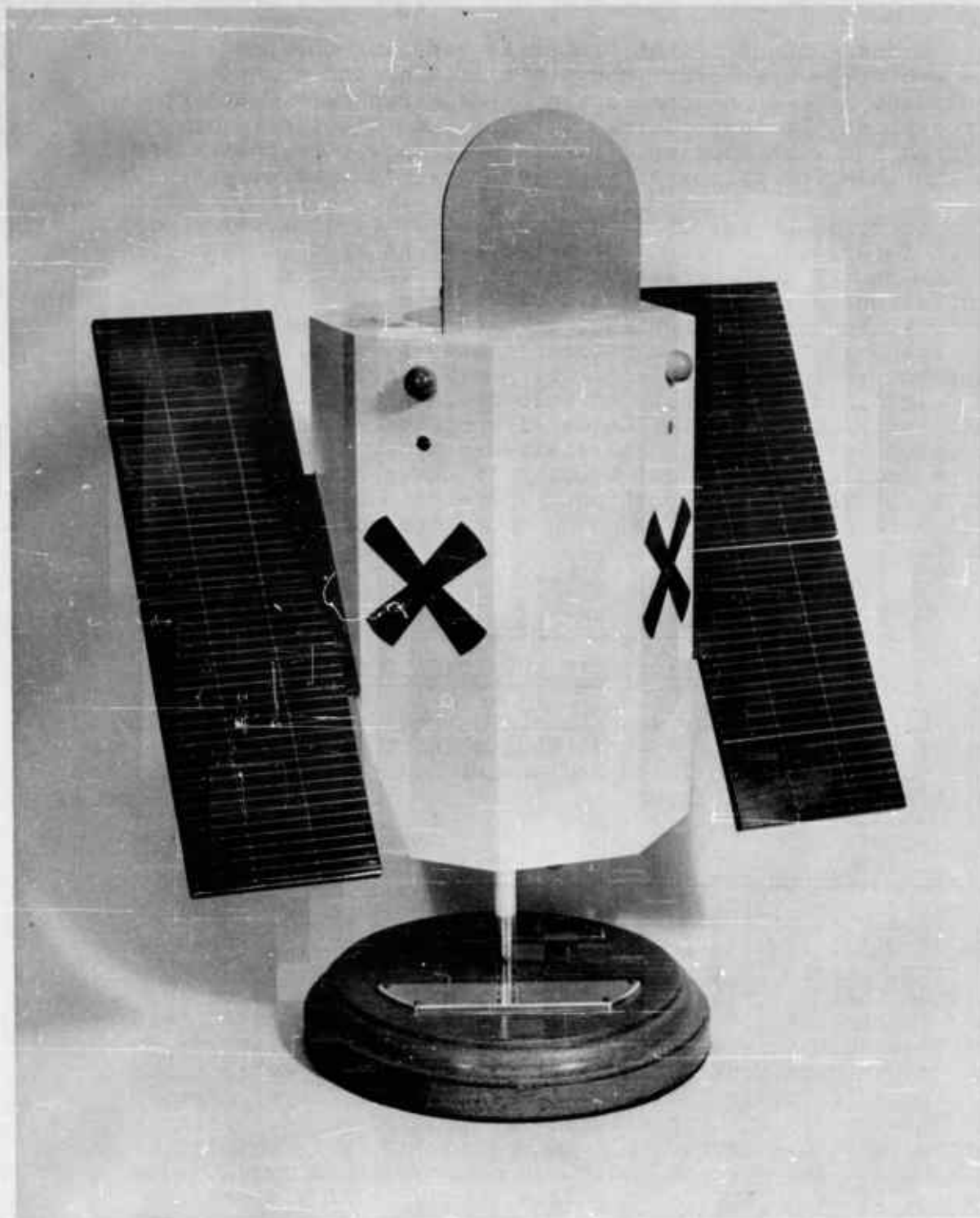
This will be the first of a series of astronomical observatory satellites designed to study the stars, sun, nebulae, and planets from above the disturbing effects of the earth's atmosphere. Precise control of the satellite's orientation and stabilization to a degree not yet attempted, must be achieved to obtain the pointing accuracy and steadiness required for astronomical observations. The satellite will be a standardized "space platform," complete with stabilization and power equipment, and capable of accommodating various types of astronomical observing equipment. Experimental equipment will include telescopes, with mirrors having diameters up to 36 inches, specialized spectrometers, photometers, and image detecting tubes. Total weight will be approximately 3,500 pounds. The satellite platform will be about 10 feet long and 10 feet in diameter. An Atlas-Agena B will be used as the launch vehicle. Plans call for a nearly circular orbit with an altitude of about 475 miles.

Goddard Space Flight Center is managing the project. Design specifications have been prepared and circulated to industry. When the report period ended, NASA had received and was evaluating 11 design proposals. Experiments suitable for inclusion in this satellite or later models are under way at Goddard, Princeton University, the University of Wisconsin, the Smithsonian Astrophysical Observatory, and the University of Michigan Observatory.

Orbiting Solar Observatory

This will be the first satellite of a series being planned to study the sun and its phenomena intensively. These studies will consist chiefly of detailed examination and monitoring of electromagnetic radiation from the sun. Prime emphasis will be on types of radiation which, because they are absorbed by the earth's atmosphere, cannot be studied from the ground.

One section of the satellite will spin to stabilize the payload gyroscopically and will house some of the instrumentation. Other instruments will be trained on the sun continuously by means of an automatic pointing control. The stabilized section and the scientific instrumentation will weigh about 100 pounds. Solar cell power supply with nickel-cadmium storage batteries will be used. An operating lifetime of one year is planned. Total weight of the satellite will be about 350 pounds. A nearly circular orbit at an altitude of about 300 miles will be sought.



A model of the Orbiting Astronomical Observatory with solar vanes extended.

Goddard Space Flight Center is managing the project. The prototype spacecraft and stabilization and pointing equipment have been constructed by Ball Brothers Research Corporation, Boulder, Colo., in close coordination with Goddard and with Douglas Aircraft Co., Inc., the contractor responsible for spacecraft and launch vehicle work.

Experiments selected for this satellite include: 1) an X-ray spectrograph; 2) a Lyman-Alpha spectrometer; 3) low-energy and high-energy gamma ray detectors; 4) neutron detectors; 5) specialized ultraviolet and X-ray detectors, and 6) an experiment to determine the effect of the space environment on materials used in satellites. Experimenters included scientists from Goddard, the University of California, University of Colorado, University of Michigan, University of Minnesota, University of Rochester, and Ames Research Center. NASA has received prototype experiments. Mechanical and electrical testing is under way at Ball Brothers Research Corporation. The second satellite of this series is planned for launching about one year after the first.

RECENT PROGRESS IN SCIENTIFIC SATELLITE INVESTIGATIONS

Highlights of the data obtained from preliminary analyses of the results of several NASA scientific satellites were noted in NASA's Third Semiannual Report to Congress. Later information follows:

Explorers VI and VII and Vanguard III

Analyses of the data from Explorers VI and VII, and Vanguard III are continuing. Explorer VII is still transmitting. Early in the spring of 1960, NASA published two reports that described the equipment and procedures to be used in receiving data from this satellite. The objective was to enable scientists throughout the world to receive and reduce data from Explorer VII. In this connection, the Institute of Physical and Chemical Research, Tokyo, Japan, has been recording transmissions from Explorer VII since April. NASA has agreed to furnish the Institute the orbital data needed for precise reduction of scientific results. The Institute is supplying NASA with copies of all data received.

Scientific Data from Echo I*

An analysis of the tracking data from Echo I by Goddard Space Flight Center shows -- as predicted -- that sunlight exerts pressure on the satellite. The large size and small weight of Echo I make it particularly responsive to sunlight pressure. The orbit of Vanguard I has also been affected to a much slighter degree, by sunlight. However, this satellite is so small that it was in orbit two years before the effect could be detected.

On Echo I the sunlight's effect is about 300 times greater than on Vanguard I, principally showing as a change in the orbit's eccentricity. The initial perigee of Echo I decreased by about 220 miles in two months. It is estimated that the lifetime of Echo I, which would have been about 20 years if there had been no sunlight pressure effect, will be shortened to one or two years.

Even though the atmosphere is extremely tenuous at Echo's altitude, it does exert some drag on the satellite. From orbital data, Goddard calculated average density of the atmosphere at an altitude of 1,000 miles to be about one quadrillion times less than at sea level. This agrees well with earlier estimates and extrapolations of data recorded at lower altitudes. It is well to note, however, that atmospheric density at these high altitudes may vary by as much as a factor of 100, depending upon solar activity.

* Launch and other details are reported in Chapter 2, "Satellite Applications," pp. 10.

Lunar, Planetary, and Interplanetary Programs

PROGRESS IN PLANNING

Organization of the NASA program for exploring the moon, planets, and interplanetary space is well under way. Noteworthy scientific results have already been obtained by the Pioneer V deep space probe (now in orbit around the sun) which, on June 26, 1960, transmitted its final message to earth from a distance of some 22,500,000 miles. Other NASA probes, satellites, and sounding rockets have added enormously to knowledge of the earth's immediate space environment. These have laid the groundwork for the coming series of progressively larger and more effective unmanned spacecraft, carrying more and more complex instruments and equipment to perform increasingly difficult scientific investigations of the moon and interplanetary space, and eventually of Venus and Mars.

Man-carrying scientific expeditions to the earth's neighboring bodies in space lie farther in the future. NASA is planning such missions, however, and the ensuing program will rely heavily on the results of the unmanned missions. The following pages deal with some of the early, unmanned steps in NASA's lunar, planetary, and interplanetary programs.

Lunar Spacecraft Being Developed

NASA plans for exploring the moon have advanced sufficiently for lunar spacecraft to be designed and placed under construction. The first of these, termed Ranger, will carry an instrument package built ruggedly enough to survive a rough landing on the moon where it will record and radio to earth seismological data that will help scientists understand the lunar structure. In 1961, NASA will begin test-flying Ranger with the Atlas-Agena B launch vehicle.

NASA has let contracts for advanced engineering studies of a soft-landing lunar spacecraft, known as Surveyor, which will be launched by the Centaur vehicle. The Surveyor is expected to be under systems contract early in 1961. Scientific instruments and other components for both Ranger and Surveyor are now being developed.

More Advanced Spacecraft Being Designed

Detailed plans are being prepared to employ the Saturn launch vehicle -- when it has been developed to full capability -- in an advanced lunar landing program called Prospector. Beyond these programs, NASA is designing spacecraft to explore Mars and Venus. Centaur, and eventually Saturn, will be used to launch various types of spacecraft which will be instrumented to transmit to receiving stations on earth scientific information about these two planets and their environments.

LUNAR PROGRAM

Data Sought on Origin of Earth-Moon and Planetary Systems

One of the chief scientific goals of NASA's lunar program is to explore and investigate the moon for information on the history of the earth-moon system and on the origin of planetary bodies in the solar system. Experiments are planned to: 1) measure the surface structure and physical properties of these bodies; 2) determine the origin of surface features and the chemical composition and properties of the moon; and 3) learn whether the moon is a solid, cold body or molten beneath the crust as is the earth.

Atlas-Able V

An unsuccessful launching on September 25, 1960, resulted in the loss of an Atlas-Able V with a spacecraft designed to orbit the moon.

Ranger

Ranger and other advanced spacecraft in the lunar series will have strongly related characteristics. The purpose of the Ranger program, comprising a series of five spacecraft, is to: 1) investigate the surface of the moon as the spacecraft approaches it, and 2) land the first U.S. survivable payloads on the surface. Hardware development has reached the prototype testing phase. Systems are being integrated and tested to establish the final configuration of the first flight-test model. In May, NASA let a \$4.8 million contract to the Aeronutronic Division of Ford Motor Co., Newport Beach, Calif., for the survivable capsule system. All elements of this system are under development; many engineering problems associated with impact structure,

packaging, electronics, etc., have been investigated at the Jet Propulsion Laboratory and at Aeronutronic facilities.

First Ranger Missions -- The first two Rangers will be alike, and in some respects simpler than the spacecraft which will be used for landing survivable packages. They will be sent on missions to: 1) test the basic design and advanced features of the lunar spacecraft, and 2) obtain scientific data about interplanetary space. They will be equipped with sensing instruments where the lunar capsules will later be carried. Experiments for the first two Rangers include three types of devices to measure radiation from the sun and from space, plus a magnetometer to map the extent of the magnetic field surrounding the earth, and a Lyman-Alpha detector that will look toward the earth to obtain data concerning the hydrogen cloud which enshrouds this planet.

Objectives of Last Three Rangers -- Each of the last three flights of the Ranger series is intended to rough-land a "capsule" of instruments and transmitting equipment on the moon. The spacecraft, a six-sided structure with two foldable panels covered with solar cells, will contain power supplies, radio, and equipment for attitude control and mid-course guidance. Each of these Rangers will carry a separable rocket stage which will include the "capsule" housing the survivable instrument package. The spacecraft itself will continue on and crash into the moon after the retro-rocket has been ignited to slow the capsule for a rough-but-safe landing.

Major Experiments -- Both the spacecraft and the capsule will carry experiments. The primary experiments on the spacecraft will be an advanced vidicon television system to photograph the lunar surface on approach and a gamma ray spectrometer to determine whether the moon's crust contains a high concentration of radioisotopes.

The major experiment in the landing capsule will be a seismometer to record earthquake, volcanic, or other disturbances within the crust of the moon. Seismic measurement can answer fundamental questions about the interior and origin of the moon. The seismometer under study is expected to operate and transmit continuously for one to three months after lunar impact.

Surveyor Soft-Landing Spacecraft

Designed for use with the Centaur launch vehicle, Surveyor is expected to carry to the moon an instrument system

weighing from 100 to 300 pounds. Study contracts, each amounting to about \$125,000, were let in July to four contractors: the Hughes Aircraft Co., North American Aviation, and Space Technology Laboratories, of Los Angeles, Calif.; and the McDonnell Aircraft Corp., St. Louis, Mo. The Jet Propulsion Laboratory is providing design requirements to the contractors as studies progress. Surveyor hardware development and fabrication should begin early in 1961. A series of short-term (four to five months) study contracts toward the development of scientific experiments for soft landing missions have been let as listed below:

Armour Research Foundation, Ill. Institute of Technology, Chicago, Ill.; \$50,502; Lunar Drill Study

Hughes Tool Co., Houston, Texas; \$36,184; Lunar Drill Study

Texaco, Inc., Texaco Bellaire Laboratory, Houston, Texas; \$49,522; Lunar Drill Study and Lunar Physical Parameters

Dresser Industries, Inc., Dallas, Texas; \$34,344; Instrumentation of Lunar Compositional Analysis Study Program and Parameters

Philips Electronics and Pharmaceutical Ind. Corp., Mt. Vernon, N.Y.; \$14,644; Instrumentation of Lunar Compositional Analysis Study Program

Kaman Aircraft Corp., Kaman Nuclear Div., Colorado Springs, Colo.; \$24,973; Instrumentation of Lunar Compositional Analysis Study Program

Bendix Corp., Cincinnati, Ohio; \$48,407; Instrumentation of Lunar Compositional Analysis Study Program

Beckman Instruments, Inc., Fullerton, Calif.; \$31,468; Instrumentation of Lunar Compositional Analysis Study Program

Aerojet-General, Inc., Azusa, Calif.; \$28,857; Gas Chromatographic Instrumentation

Surveyor will be the first U.S. spacecraft capable of making a controlled landing on the moon. It will be equipped with instruments to make a detailed television survey of the landing area and to measure the general properties of the moon's surface and composition.

Lunar Orbiters Based on Surveyor -- A step beyond Surveyor will be the adaptation of its soft-landing system to lunar orbiting missions. The orbiters will be interspersed with soft-landers to provide low-altitude mapping and to determine mass distribution, magnetic fields, radiation, and other lunar characteristics better obtained by orbiting the body than by landing. Because a long period of development is involved, NASA let study contracts in August for the instruments of the visual-observation subsystem for the orbiters, as follows:

Eastman Kodak Co., Apparatus and Optical Division, Rochester, N.Y., \$69,800; Fairchild, Dumont Military Electronics Dept., Clifton, N.J., \$48,400; and RCA, Astroelectronics Division, Princeton, N.J., \$51,000.

Prospector

Designed for controlled lunar landings, Prospector will use the Saturn launch vehicle and will weigh about 5,000 pounds at touchdown. NASA is conducting studies to determine requirements for the spacecraft. The typical Prospector lunar mission is designed around the use of instrumented, roving surface vehicles. Final design of the Prospector series will be directly influenced by information obtained from Ranger and Surveyor missions. Study of specialized experiments for Prospector has begun at JPL.

PLANETARY MISSIONS

Long-Term Objectives

After the moon and its environment have been explored with instrumented devices, NASA plans to extend its unmanned exploration of space to the nearer planets. Attempts will be made to:

1. Place in orbits about Mars and Venus spacecraft capable of gathering fundamental scientific knowledge of the planetary environments and of the planets themselves.
2. Map and investigate interplanetary space and the sun's influence on it.
3. Develop (in cooperation with the lunar and other space flight programs) a spacecraft technology to provide: 1) long-lived scientific instruments,

2) guidance and communications, and 3) capsules for entering the atmosphere and landing.

On March 11, 1960, a Thor-Able launched Pioneer V into a solar orbit (see below). In 1961 a Thor-Delta will be employed to launch a probe to measure interplanetary magnetic, particle, and radiation fields. In 1962 NASA will begin the Mariner series by launching a Venus probe using a Centaur vehicle. These missions are described in detail in the following sections.

Pioneer V Orbital Elements

As discussed in NASA's Third Semiannual Report to Congress, Pioneer V was eminently successful. During ensuing months, orbital elements computed 16 hours after launch have proved to be extremely accurate:

<u>Period:</u>	311.6 days
<u>Time to perihelion:</u>	152 days
<u>Eccentricity of orbit:</u>	0.104
<u>At perihelion (August 10, 1960):</u>	
<u>Sun-probe distance:</u>	74.9 million miles
<u>Earth-probe distance:</u>	46 million miles
<u>Probe velocity about sun:</u>	78,000 miles per hour
<u>At aphelion (January 13, 1961):</u>	
<u>Sun-probe distance:</u>	92.3 million miles
<u>Earth-probe distance:</u>	84 million miles
<u>Probe velocity about sun:</u>	63,300 miles per hour

Communications -- From the time the first command, "Separate payload from third stage," was sent by the Jodrell Bank facility, Manchester, England, 25 minutes after liftoff, until communication was ended in July, all elements of the telemetry system worked well. Commands to vary the transmission rate of the 5-watt transmitter were sent in March and the search frequency bandwidth of the on-board receiver was altered in April. Several times during May, early termination of the transmission from Pioneer V indicated a gradual

weakening of the solar cell-battery power system. NASA scientists decided to try the 150-watt transmitter. This was done successfully on May 8. Transmission periods with the high-power transmitter continued to decrease. After the May 21 contact, 5-watt operation was resumed. Communications were maintained until June 26, when Pioneer V was 22,500,000 miles from earth. During 106 days of active life, the probe had transmitted 138.9 hours of data.

Scientific Results -- Aside from its communication feats, Pioneer V established these major scientific "firsts":

1. Instruments detected solar particles in transit between the sun and the earth, millions of miles from earth.
2. Sudden decreases in cosmic ray intensity--called the Forbush decrease--do not appear to depend on the earth's magnetic system, as has long been theorized.
3. The high-energy levels of the particles in the outer parts of the Great Radiation Region around the earth are not produced directly by electrons from the sun. Pioneer V and Explorer VII measurements made simultaneously indicate that the electrons are somehow accelerated to greater speeds after being caught in the earth's magnetic field.
4. Magnetometer data can be explained by the existence of a large ring-current circulating around the earth at altitudes from about 30,000 miles to 60,000 miles. Total current flowing inside this region of space has been computed to be 5 million amperes.
5. Evidence was provided that the earth's magnetic field extends to a distance of 64,000 miles.
6. Existence of a measurable interplanetary magnetic field is suggested by Pioneer V findings.

Magnetometer Probe

Early in 1961, NASA plans to launch a Thor-Delta, carrying a magnetometer probe, on a course to the edge of interplanetary space (at least 120,000 miles from earth) to measure magnetic fields and particles. Instruments will include a rubidium-vapor magnetometer, which can detect weaker fields than previous instruments, a fluxgate magnetometer to record the direction of the field, and a plasma

probe to measure the flux of low-energy positive particles. The plasma probe was built at M.I.T., the other instruments at Goddard.

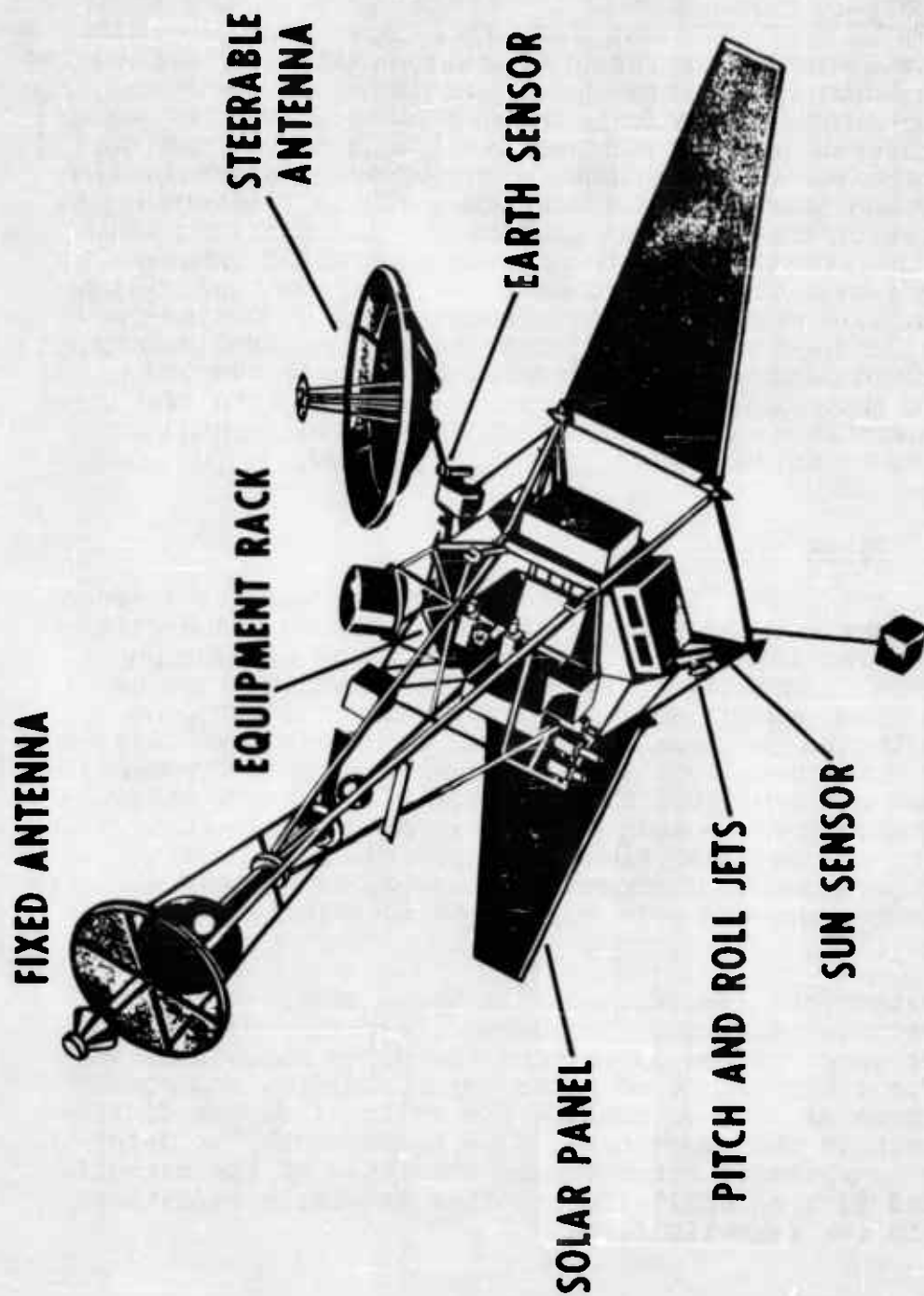
Mariner Fly-by Series

These NASA spacecraft for missions to Venus and Mars are being designed to fit the capabilities of the Centaur launch vehicle. Missions in which the spacecraft "flies by" target planets (coming within a few planet radii) are logical early steps because scientific information they gather will not only add to fundamental knowledge but will provide data upon which to base the development of more refined instruments. Much of the technology needed for later planet-orbiting spacecraft can be tested and evaluated on fly-by missions. According to NASA's present plans, the Mariner series will include a fly-by of Venus in 1962, flights deep into interplanetary space in 1962 and 1963, and missions to Venus and Mars in 1964. An important objective of the first three launchings will be to proof-test the spacecraft, including all sub-systems (guidance, attitude control, communications, etc.).

Venus Mission Objectives

The first questions that must be answered about Venus concern the nature of the planet's atmosphere, its surface temperature, its rotation rate and spin axis, its magnetic field and the radiation region surrounding it. Because Venus is veiled in dense clouds, the surface cannot be seen from earth -- hence, the rotation rate is unknown. The structure of the atmosphere is of great scientific interest since it will provide information required to reconstruct a history of our solar system. Also, knowledge of the pressure, temperature, and constituents of Venus' atmosphere is of immediate importance in planning long-range planetary programs.

Instruments contemplated for Venus missions include: 1) a microwave radiometer to measure temperature; 2) an ultraviolet spectroscope to examine the upper atmosphere and search for the presence of water vapor, oxygen, and ozone; 3) a neutron counter to measure the ratio of carbon dioxide to nitrogen in the atmosphere; 4) a magnetometer to determine the approximate strength and character of the magnetic field; and 5) a scintillation counter to sample radiation trapped in the magnetic field.



NASA SLIDE 2608

Principal components of the Ranger and Mariner spacecraft designed for unmanned lunar and interplanetary exploration.

Mars Mission Objectives

The central question about Mars is whether life exists on that arid planet, as some astronomers believe. Early experiments will be designed to seek evidence of living matter. An infrared spectograph will be carried to determine whether organic molecules necessary for life, as we know it, exist and, if so, where. The upper atmosphere will be examined for ozone to learn if the surface of the planet is protected from ultraviolet radiation which, in large doses, is damaging to terrestrial life. Mars missions will thus probably retain the ultraviolet spectrometers, magnetometers, and scintillation counters used in Venus missions, but radiometers would be replaced by infrared spectrometers. In addition, since the Martian atmosphere is relatively clear, the spacecraft will carry an optical system mated to a vidicon television camera capable of taking photographs at one kilometer resolution. Over-all mission studies, as well as preliminary design of the spacecraft missions, are being conducted by NASA's Jet Propulsion Laboratory. Many components of the Mars spacecraft -- including major subsystems -- will be fabricated by industry.

Voyager Orbiter Series

Preliminary mission studies are under way for a second planetary series, the Voyager orbiters. These spacecraft will be designed to orbit Venus and Mars and will be phased in time and capabilities with the Saturn launch vehicle. If Mars and Venus can be orbited successfully and for long periods, it will be possible to make excellent investigations of their environments. Landing capsules dropped from spacecraft will provide details of the lower atmosphere and surface. Instruments aboard the orbiter can also evaluate planetary mass and mass distribution. According to present thinking, scientific experiments planned for Voyager will be advanced versions of those for the Mariner series.

Tracking and Data Acquisition

KEEPS PACE WITH SPACE EXPLORATION

Expansion and improvements of NASA's tracking and data acquisition systems have kept pace with progress in the Nation's space effort. Developments in the Project Mercury tracking network are reported in Chapter 3, Manned Space Flight, pp. . Advances in other NASA tracking-network activities follow.*

MINITRACK NETWORK

Construction

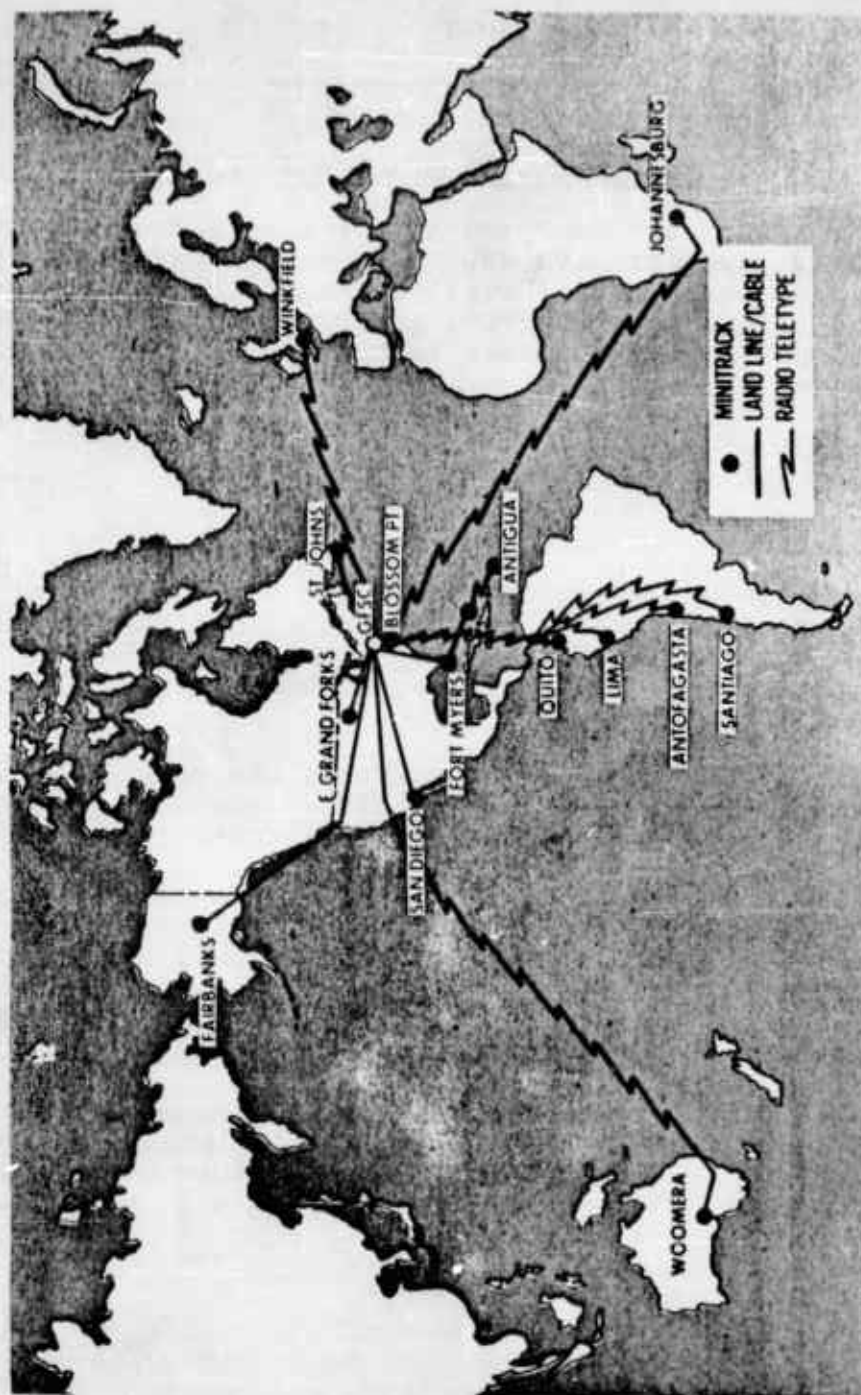
NASA is extending the satellite tracking coverage provided by the Minitrack network by constructing four high-latitude stations at East Grand Forks, Minn.; Fairbanks, Alaska; St. Johns, Newfoundland, Canada; and Winkfield, England. (See map, p. 68.)

The station at East Grand Forks has been constructed and that at Winkfield is about half completed. The Winkfield station is expected to be operational by early 1961.

NASA has advertised for bids from Canadian firms to construct the St. Johns station which is scheduled to be operational by February 1961. At Fairbanks, work on foundations, roads, and buildings began in August, and delivery of tracking equipment was complete. Bad weather is expected to delay finishing the station until next spring.

NASA has purchased land to install an 85-foot antenna next to the Fairbanks station. The antenna will be employed for Polar orbiters such as the Nimbus meteorological satellite. To date, NASA satellites have had east-west orbits.

* Diplomatic negotiations for oversea tracking stations are covered in Chapter 9, International Programs, p. 111.



NASA's world-wide Minitrack tracking and data acquisition network showing station locations and forms of communications. The network is intended primarily for unmanned satellites.

Control Center Moved

On June 18, 1960, NASA completed transfer of the Mini-track Control Center from Washington, D.C., to Goddard Space Flight Center, Greenbelt, Md. Goddard directs both the Minitrack and Mercury networks.

Standardization of Telemetry Systems

In order to simplify tracking and data acquisition, NASA intends to use two standardized telemetry systems. For small satellites, the agency will employ a pulse-frequency system possessing the advantages of minimal weight, space, and power requirements and capable of providing significant quantities of moderately accurate data.

NASA will use the bigger and more complex pulse-code system for large satellites. The pulse-code system more than compensates for its greater weight and size by the substantially greater amount of data it provides and the relative ease in decoding its signals.

The pulse-code system transmits information to ground stations by a series of pulses, the presence or absence of which conveys information based upon a predetermined code. The pulse-frequency system provides data by variations in tone -- each sound higher or lower on a musical scale.

Automatic Data Read-Out System

A prototype automatic data read-out system began operation in the Minitrack control room of the Goddard Space Flight Center, Greenbelt, Md., after successful tests at the Blossom Point, Md., Minitrack station. NASA plans to equip all Minitrack stations with this system which can increase station tracking capabilities about 50 percent without employment of additional personnel. NASA is continuing developmental studies of the system to increase its effectiveness and diversify its applications.

Photoelectric Optical Tracking Equipment

Design of a photoelectric optical tracking system has begun. This equipment is superior to existing photographic systems because it is more sensitive and provides data instantaneously.

Conversion of Tracking Frequencies

By the end of the report period, new 136 - 137 megacycle antennas had been installed at six stations: Blossom Point, Md.; Fort Myers, Fla.; Antofagasta and Santiago, Chile; Lima, Peru; and Quito, Ecuador. It is anticipated that all Minitrack stations will have the new antennas in early 1961.

The new frequencies were allocated to the United States by the International Telecommunications Union. They replace the interim 108-megacycle frequency assigned to Minitrack during the International Geophysical Year.

DEEP SPACE NETWORK

Can Provide Continuous Communication with Interplanetary Craft

The Deep Space Instrumentation Facilities at Goldstone, Calif.; Woomera, Australia; and Krugersdorp, Union of South Africa, will provide continuous communication with lunar and interplanetary spacecraft. This is due to the large antennas and to the spacing of the stations at 120° intervals so that at least one will have a line-of-sight communications field with the spacecraft despite the earth's rotation.

Construction

Transmitting facilities at Goldstone were completed in time for the station to participate in the Echo I satellite experiment (see Chapter 2, Satellite Applications, pp.10).

Construction of the receiving station at Woomera, Australia, is expected to be completed late in 1960. The Australian Department of Supply will eventually man its 85-foot antenna.

Site surveys and other groundwork for the Krugersdorp station, which is 30 miles west of Johannesburg, were completed by the end of September. The South African Council of Scientific and Industrial Research will staff the station when it is operating in 1961.

Studies of Larger Antennas Begin

NASA has started studies of larger antennas for its Deep Space stations. The Jet Propulsion Laboratory,

Pasadena, Calif., which directs the Deep Space tracking network, has published requirements for a large antenna (in the 250-foot class) that would increase the Goldstone station's range 10 to 20 times. This publication was distributed to firms interested in submitting proposals for a feasibility study contract.

OPTICAL TRACKING

NASA spacecraft are also tracked by a worldwide optical network consisting of 12 Baker-Nunn telescopic camera systems. The camera and layout of a typical Baker-Nunn installation are illustrated on page 72. The Smithsonian Astrophysical Observatory, Cambridge, Mass., technically directs the Baker-Nunn network.

SUPPORTING ACTIVITIES

Jodrell Bank Telescope Contract Extended

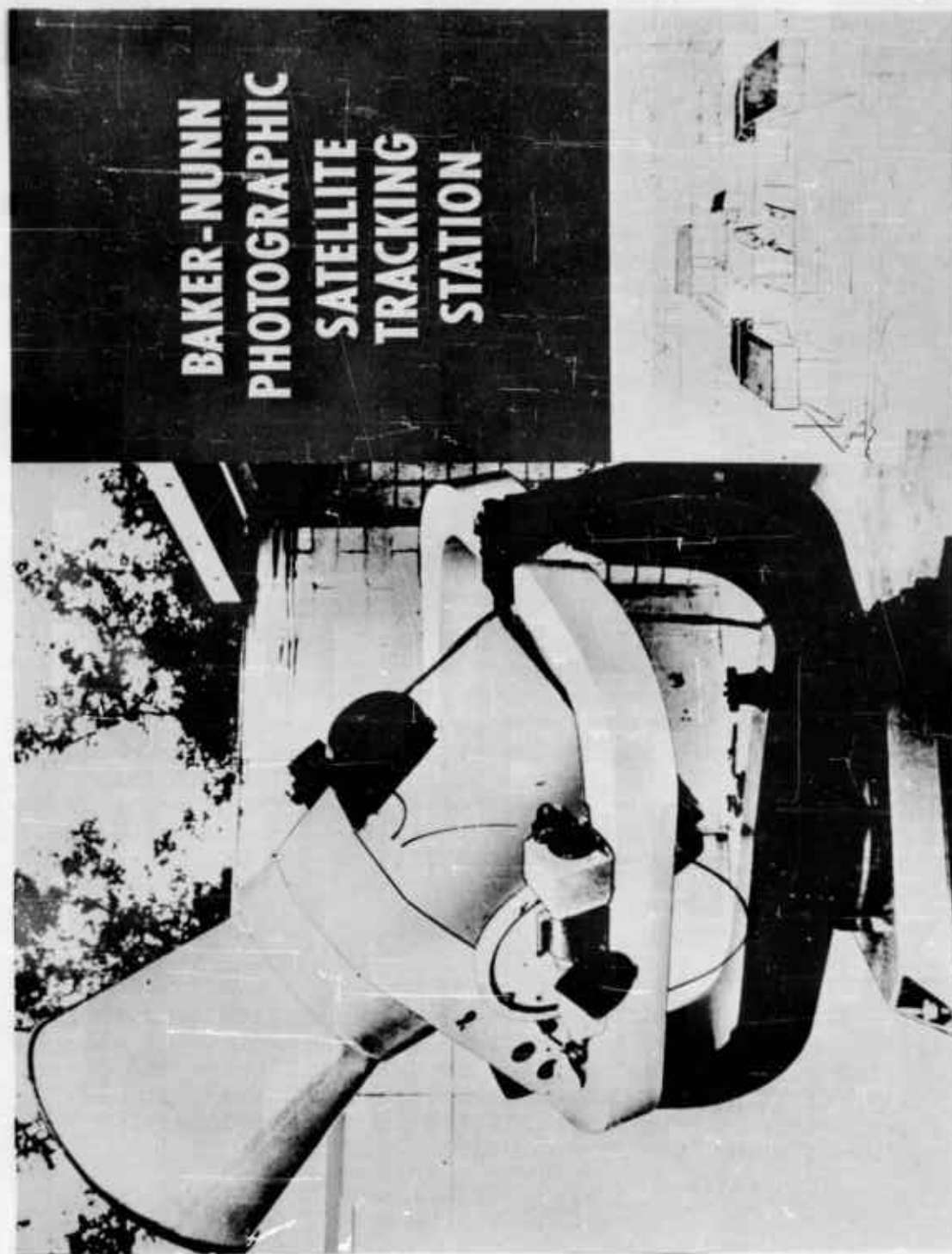
In May 1960, NASA and the University of Manchester, Manchester, England, extended to December 31, 1961, their contract for use of the Jodrell Bank radio telescope, Cheshire, England, in NASA space programs.

Navy To Support TIROS

On July 27, 1960, NASA and the Department of the Navy agreed to Pacific Missile Range support of the TIROS meteorological satellite program to August 31, 1961. This agreement includes employment of the 60-foot diameter radar antenna on San Nicholas Island, Calif. The agreement assigns top priority for use of the facility in two planned TIROS launchings.

Plans for Centaur Support

NASA completed plans for instrumentation to support initial missions of the Centaur launch vehicle. It will utilize existing equipment up to the first three and possibly the first six Centaur launchings; however, it will augment telemetering capabilities at the stations with equipment specifically for Centaur support.



At lower right is a typical Baker-Nunn tracking station layout. At left is the giant Baker-Nunn precision camera.

SECTION III

LAUNCH VEHICLE PROGRAMS

Launch Vehicles and Launch Operations

STANDARDIZED VEHICLES READIED

Through mid-1960, most NASA launch vehicles owed their parentage to components developed in either the Department of Defense programs or in Project Vanguard, the U.S. space program for the International Geophysical Year. NASA has begun replacing these vehicles with the first of a fleet of standardized units. Through repetitive use of the new vehicles, the agency expects to achieve a high degree of reliability.

Vanguard and Jupiter C Programs Completed

Vanguard and the Army-developed Jupiter C have been phased out. The Jupiter-based Juno II and Thor-Able programs will be completed in 1961. Delta, an improved Thor-Able, will not be used after next year. These vehicles have the following low earth-orbital capacities: 1) Jupiter C, 35 pounds and Vanguard, 50 pounds; 2) Juno II, 95 pounds; 3) Thor-Able, 200 pounds; and 4) Delta, 480 pounds. Succeeding them are: 5) Scout, 150 pounds; and 6) Thor-Agena B, 1,600 pounds.

Scout

Scout is a four-stage, all solid propellant vehicle, designed for reliability, versatility and relatively low production cost, i.e., about \$750,000 each. It is the smallest of the basic NASA family of launch vehicles. Scout's capabilities include orbital, probe and re-entry missions planned to fulfill a large variety of requirements for small payloads.

Thor-Agena B and Atlas-Agena B

Thor-Agena B is basically the same vehicle as that used in the U.S. Air Force Discoverer satellite program. Agena B is a 15,000-pound thrust liquid-fuel rocket stage; Thor has a thrust of 165,000 pounds. The first two-stage Thor-Agena B is scheduled for launch in March 1962. In a

more powerful class is Atlas-Agena B. With Atlas (360,000-pound thrust at lift-off, 80,000-pound thrust in sustainer stage), the Agena B will launch 750-pound probes to the moon -- including hard-landing payloads on its surface -- and 5,000-pound earth satellites. The first Atlas-Agena B is scheduled for launch in mid-1961.

Atlas-Centaur

Beyond the Agena vehicles in capability is Atlas-Centaur, scheduled for its first flight in 1961. Atlas-Centaur will be the first U.S. launch vehicle to employ a high-energy upper stage, using liquid hydrogen-liquid oxygen (LOX) instead of the conventional combination of kerosene and LOX. The Centaur second stage is powered by two rocket engines, each generating 15,000 pounds of thrust. The vehicle's capability: 8,500-pound earth satellites, and 1,450-pound lunar orbiters and planetary probes.

Saturn

Saturn Is Largest Vehicle -- The largest U.S. vehicle under development is Saturn, the first stage consisting of a cluster of eight liquid-fuel engines totaling 1.5 million pounds of thrust. Mounted on the cluster in the first (C-1) version will be two hydrogen-oxygen upper stages. C-1's capacity: 19,000 pounds in earth orbit, 5,000 pounds on a lunar trajectory.

Second-generation versions of Saturn are under consideration. The second model, the three- or four-stage C-2, will carry a second stage with four 200,000-pound thrust, liquid hydrogen-liquid oxygen engines.

Study Saturn Successor -- During 1960, much study was devoted to defining the launch vehicle to follow Saturn. The principal mission used as an objective has been that of landing a manned spacecraft on the moon, and returning the man to earth.

Nova

One of a number of possible vehicles under study is Nova. This concept envisages employing the single-chamber 1,500,000-pound thrust F-1 engine, now being developed.

Under this approach, a number of F-1 engines will be used in the first stage and hydrogen-oxygen stages will be mounted on the giant first stage. In these vehicles, the propulsion system is based on existing engines in which a fuel is mixed with an oxidizer and burned in a combustion chamber. The resulting high-temperature gas is accelerated through a jet nozzle to propel the vehicle.

For the initial power to break away from the earth's gravitational pull, high thrust of short duration is needed. Once the vehicle is in space, however, relatively low-thrust but high, exhaust-velocity propulsion operating for much longer time periods is possible.

Nuclear and Electric Propulsion

To meet the above second need, NASA is pursuing two advanced propulsion programs. One is a vehicle in which a nuclear reactor (instead of chemical combustion) heats the propellant and expands it through the nozzle. The second system employs electrical propulsion. (See Chapter 8, Propulsion and Nuclear Energy Applications for Space, pp.87.)

During the report period, the following progress was made in the launch vehicle program:*

Scout Flight Tested

Scout X - On April 18, a dummy Scout was launched to test operation of the new launch tower and the newly developed third stage engine. A structural failure caused by an excessive vehicle roll rate prevented ignition of the third stage engine. Operation of the launcher and first stage burning were satisfactory (second and fourth stages were dummies).

First Complete Scout Launched on July 1

The first complete four-stage Scout was launched on July 1 from Wallops Island. This was the first time that guidance and control had been used on a four-stage all solid

* Detailed descriptions of the vehicles' components, fuels, etc., were provided in NASA's Third Semiannual Report to Congress.



A prototype Scout launch vehicle produces billows of smoke and flames as it rises from Wallops Station, Va., on July 1.

propellant vehicle. Operation of the first three stages was satisfactory; however, ignition of the fourth stage was prevented when the vehicle appeared to veer off course. Investigation indicated that faulty operation of the ground radar gave incorrect track information and that the vehicle had actually been on course. The third and fourth stages, locked together, reached an altitude of 860 miles before landing in the Atlantic Ocean 1,500 miles from Wallops.

The flight was long enough to test the complete guidance and control system and provide answers to several development problems. In particular, the test indicated that additional roll control was required for the third stage. This modification has been accomplished.

First Delta Test

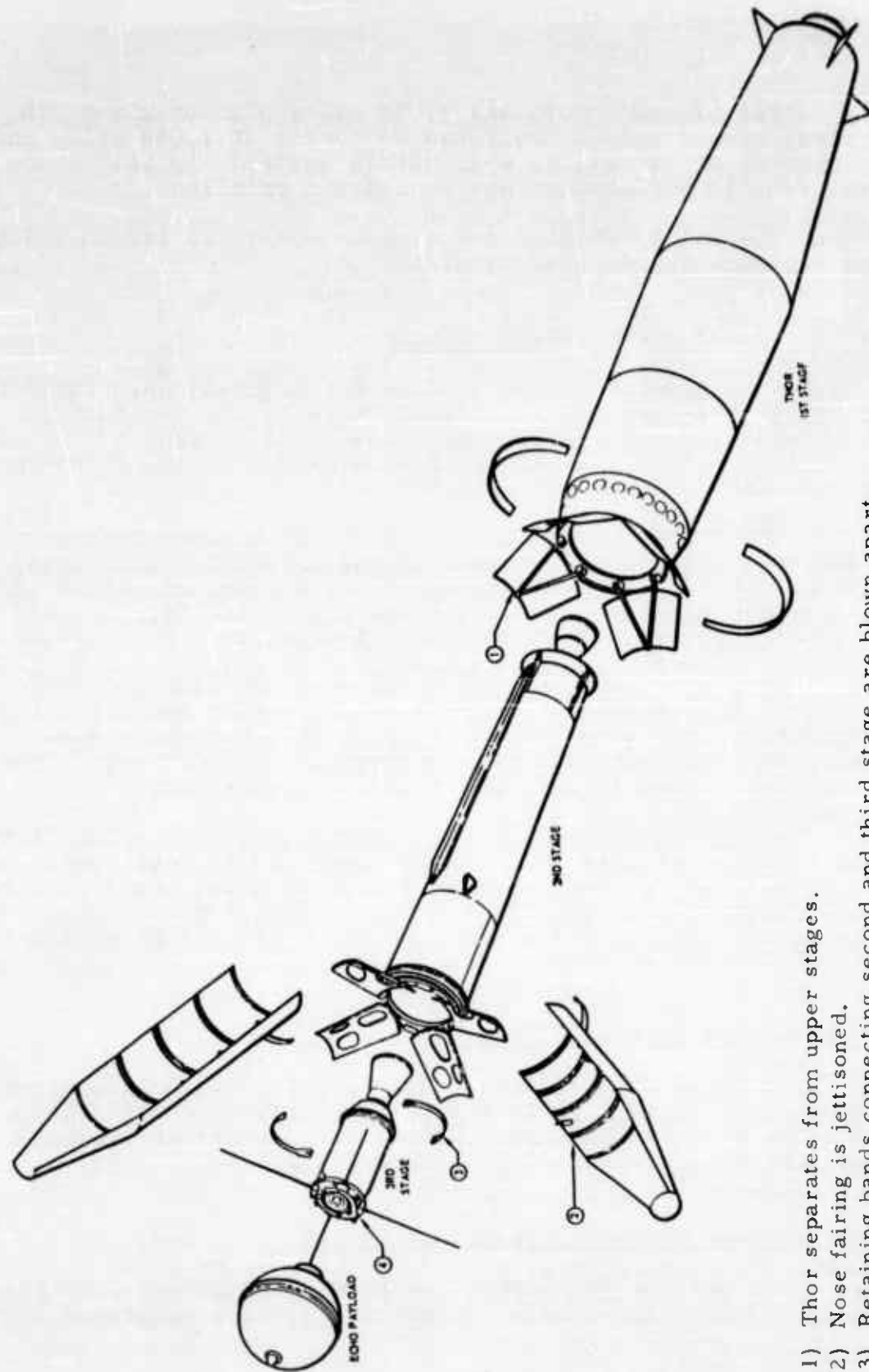
The first complete three-stage Delta was launched from AMR on May 13 carrying a Project Echo inflatable satellite. The first two stages fired but the coast-attitude control system in the second stage malfunctioned and the third stage was not ignited. The vehicle reached an altitude of 1,000 miles.

Delta No. 2 Attains Objectives -- Delta No. 2 fired the Echo I passive communications satellite into orbit on August 12. (For other Echo I details see Chapter 2, Satellite Applications, pp.10.)

After lift-off from AMR at 5:39 a.m. EDT, the first stage (a modified Thor) burned for 2-1/2 minutes and separated on schedule. The second stage burned for approximately two minutes following the prescribed flight path under control of the Bell Telephone Laboratory radio-guidance system, which also commanded second-stage shutdown.

At second-stage shutdown, the vehicle was within two miles of its planned position and within 25 feet per second of the planned velocity of 29,580 feet per second or about 20,000 mph. While second and third stages then coasted for 15 minutes and 10 seconds, the flight controller oriented the vehicle for third stage spin-up, separation, and firing which took place about 20 minutes after lift-off.

The third stage burned for 42 seconds. After it coasted for two minutes, small rockets were fired to de-spin it. Two seconds later, the payload separated and two seconds after separation, another small rocket was fired to tumble the rocket casing out of the way. The sphere was injected into orbit at 6:02 a.m. EDT.



- 1) Thor separates from upper stages.
- 2) Nose fairing is jettisoned.
- 3) Retaining bands connecting second and third stage are blown apart.
- 4) Small retro-rockets of third stage fire after payload is injected into orbit.

Separation sequence in Delta launch of the Echo I communications satellite on August 12, 1960.

The planned orbit was 1,036 miles plus or minus 115 miles. The attained orbit had an apogee of 1,049 miles and a perigee of 945 miles, well within desired limits. Overall vehicle performance was considered excellent.

The Delta vehicles are also scheduled to launch TIROS, an experimental weather satellite.

Nine Agena B Stage Under Contract

Nine Agena B stages -- five for Atlas-Agena, four for Thor-Agena -- are under NASA-Air Force letter contract to Lockheed Aircraft Corp., Sunnyvale, Calif. Eight additional vehicles, making a total of 17 -- nine for Atlas, eight for Thor -- are planned through 1963.

The first of the nine stages is being assembled at Sunnyvale for delivery to AMR in April 1961 for the first Atlas-Agena launching in mid-1961. The remaining eight stages for the Thor- and Atlas-Agena programs will be delivered at approximately three-month intervals.

Thor-Agenas To Use PMR -- Current experiments being prepared for Thor-Agena flights require polar orbits -- the advanced Nimbus meteorological satellite, for example -- hence the vehicles will use the Pacific Missile Range. The first NASA Thor-Agena flight is set for mid-1962.

Atlas-Agena B will Launch Ranger Capsules -- The first two Atlas-Agena B launchings are scheduled to test components in high eccentric orbits as pre-lunar flights; the last three will attempt to rough-land survivable Ranger data capsules on the moon's surface. A launch pad (No. 12) will be modified at AMR for the Atlas-Agena B.

Marshall Has Technical Direction

Marshall Space Flight Center provides technical direction of the Agena B vehicle program. Systems contractor is Lockheed Missiles and Space Division. Engines are being built by Bell Aircraft Corp., Buffalo, N.Y.

NASA Expands Centaur Development Period

The Centaur development program has expanded from six to 10 flight-test vehicles to provide greater assurance of

reliability in the operational vehicles to follow. The first flight test is still scheduled for the second quarter of 1961 but the first operational flights have been moved from 1962 to 1963 because of the increased number of test flights.

Propulsion Systems Tests Begin -- The following developments also took place during the report period:

...Two-engine cold-flow ground tests on the liquid hydrogen engine began at West Palm Beach, Fla.

...Two hydrogen engines were shipped from Pratt & Whitney to Convair-Astronautics,* San Diego, Calif., and one was shipped to Lewis Research Center for further ground-testing.

...Final assembly began on the first Atlas stage (for Centaur C-1) at Convair Astronautics.

...The first inertial guidance system was shipped by Minneapolis-Honeywell Regulator Co., St. Petersburg, Fla., to Convair-Astronautics for environmental testing.

...Centaur C-1 and C-2, and the Propulsion Test Vehicle for use at the Government-owned, Convair-operated Sycamore Canyon test site near San Diego were in final assembly at Convair-Astronautics.

...Pad 36, the Atlas-Centaur launch complex at AMR was 75 percent complete.

...Construction of the S-4 static test stand at Sycamore Canyon, Calif., (the Convair-Astronautics test area near San Diego) continued.

...Flight missions for the 10 developmental missions were established.

...Fifteen-second periods of true zero-g flight of a cryogenic test package in the KC 135 airplane had been achieved. These tests will provide information on the behavior of liquid hydrogen under the zero-g conditions to be met by Centaur during the coasting phases of its flight.

* Convair-Astronautics is part of the Convair Division of General Dynamics Corp.

Marshall Develops Saturn First Stage

The first stage (S-1) of Saturn is being developed by Marshall Space Flight Center. It utilizes eight Rocketdyne H-1 engines, each delivering 188,000 pounds of thrust at sea level for a total thrust of about 1,500,000 pounds. These engines are simplified and uprated versions of the well-proven engines used in Atlas, Thor, and Jupiter, so the individual engine reliability is expected to be high. Experimental data to date confirm this expectation.

Engines Use LOX and RP-1 -- The engines use liquid oxygen and RP-1 (a designated type of kerosene); the propellant is carried in a cluster of eight elongated Redstone-type tanks 70 inches in diameter, surrounding one central elongated Jupiter-type tank, 105 inches in diameter. Any of the engines can be individually shut off when an incipient malfunction is detected. This provision may be compared to the redundancy implicit in a multi-engine airplane.

Complete First Static Test Series -- The first series of Saturn static tests was completed on June 15 with a 122-second firing of the complete eight-engine prototype Saturn first stage at Marshall. Results of the series were considered highly satisfactory.

Stage Designated SA-T -- The stage, designated SA-T with interim engines of 165,000-lb. thrust, was erected in the Static Test Tower on February 20; two- and four-engine tests were carried out on March 28 and April 6. On April 29, the first full-scale firing of the complete eight-engine cluster took place. Duration time was eight seconds. On May 17, the second full-scale test lasted 25 seconds. In both tests, more than 1.3 million pounds of thrust was generated.

Complete eight-engine static tests were also conducted on May 26 (35 seconds), June 3 (75 seconds), June 8 (110 seconds), and June 15 (122 seconds). Planned flight duration is about 115 seconds.

Three Problem Areas -- Before the first static test series, which was completed one month ahead of schedule, the Saturn designers were concerned with three potential problems: 1) achieving satisfactory distribution of propellant to all eight engines; 2) preventing excessive base heating in the engine area; and 3) preventing excessive vibration throughout the vehicle, especially in the engine area. In the first test series none of these potential problems proved to be major sources of difficulty.

Will Simulate Launch Model -- Second-series static tests of the Saturn prototype first stage will begin late in 1960, several months behind the schedule proposed at the end of the first series of tests. The delay was caused by NASA's decision to simulate the first flight model as closely as possible by employing: 1) on-board pressurization; 2) flight-type engines instead of research and development engines; and 3) flight instrumentation. The development schedule calls for a flight test late in 1961 with the SA-1 vehicle, which will carry dummy upper stages.

Component Fabrication Progresses -- Fabrication of components and assembly of the test-flight version of the first stage began late in May.

On July 28, NASA signed a \$68,800,000 contract with Douglas Aircraft Co., Inc., Santa Monica, Calif., to develop and produce 10 second stages for the first series of Saturn launch vehicles designated C-1. Each stage will consist of four uprated (17,500-pounds thrust each) Centaur engines which will use liquid oxygen-liquid hydrogen as propellant. Each cluster will generate a thrust of 70,000 pounds. Douglas and Marshall personnel are at work on the detailed design. Delivery of the first unit is scheduled for June 1962. The second-stage engines will be supplied by the Pratt & Whitney Division of United Aircraft Corp., East Hartford, Conn., which is developing the engine under a NASA letter contract dated August 8.

Static testing of the C-1 second stage will take place at Douglas's Sacramento test facility.

C-1 Third Stage Contract To Be Let -- Since the third stage (S-V) of the C-1 will be a modified Centaur stage, it will be developed by Convair-Astronautics, the developers of Centaur.

An initial contract was signed in June 1960 with Convair-Astronautics which is producing dummy S-V stages for the first six Saturn test vehicles.

The results of the Centaur development program itself should prove useful in the design and development of the S-V stage as well as provide useful data for S-IV development.

A final contract for the S-V stage will be signed with Convair early in 1961.

Contract for Advanced Second-Stage Engine Signed -- On September 1, NASA negotiated a \$44,000,000 contract with Rocketdyne Division of North American Aviation, Inc., Canoga

Park, Calif., to develop a second stage engine for the projected C-2 version of the Saturn launch vehicle. The contract specified that this liquid-hydrogen second stage develop 200,000 pounds of thrust. The contract also calls for preliminary flight-rating tests to be completed in 30 months and for engine flight qualification to be completed in 45 months. Clustered, these engines (designated J-2) will increase the payload for a spacecraft to nearly three times that of the C-1.

Dynamic Test Stand Being Constructed -- On August 1, construction began at Marshall on a 204-foot-high dynamic test stand for Saturn. Designed to carry out operational, mechanical, and structural tests before the first Saturn flight, the stand will have a stiff-leg crane 75 feet high with an 80-foot boom and a 50-foot mast.

New Data Processing System Installed -- A new data-processing system for the Saturn project was installed at Marshall during June and July 1960. It consists of two IBM 7090 high-speed digital computers on which Saturn will be "flown" mathematically. This capability is a strong factor in enabling engineers to use as few as 10 actual test flights. The 7090 will also facilitate the reducing and analyzing of data from Saturn static tests.

Launch Facilities Progress -- All Saturn launches are now scheduled at AMR where the following work is underway:

Complex 34: Now under construction, it consists of a blockhouse, launch stand service tower, "umbilical" tower, fuel facility, LOX facility, liquid hydrogen storage and transfer facility, operations support building, and associated ground support equipment. It will ultimately handle all C-1 configurations, including the first stage test vehicles. Installation of equipment in the blockhouse is now under way.

Complex 37: A second launch facility has been authorized by Congress and is now being designed. Complex 37 will accommodate the C-1 configuration as well as the first and second stage combination. This complex will contain the same general items as Complex 34, but will be designed so that, with changes in Saturn configuration, modification can readily be made.

A study is under way at Marshall to establish the feasibility of building mutually supporting back-up capability into Complexes 34 and 37.

Saturn First Stage Transportation: The size of the Saturn first stage (22 feet in diameter) precludes overland shipping from its assembly point at Huntsville, Ala., to Cape Canaveral, either by rail or highway because of bridge clearances, etc. A water route was selected via the Tennessee, Ohio and Mississippi Rivers, Gulf of Mexico, Atlantic Ocean, Indian and Banana Rivers, requiring about 25 days transit time. In addition, special loading and handling facilities at both ends of the line were required, as well as a special barge, dredging of canals, and raising of a bridge in Florida. The barge is being constructed by Todd Shipbuilding Co., of Houston, Texas, and will be delivered to Huntsville in November 1960. A loading dock on the Tennessee River has been completed. The unloading dock at Cape Canaveral and the dredging of the canal in the Banana River is under contract to the Duval Engineering Co. Raising of the Florida bridge over the Banana River was funded and accomplished by the State of Florida.

Personnel Transfer on July 1* -- On July 1, most of the personnel of the Development Operations Division of the Army Ballistic Missile Agency was transferred to NASA as the nucleus of the George C. Marshall Space Flight Center. This team is responsible for managing all system development of the Saturn vehicle as well as developing the S-1 stage "in house."

Test F-1 Engine's Thrust Chamber

Rocketdyne Division of North American Aviation, Inc., contractor for the F-1 engine, completed short-duration static tests of its uncooled thrust chamber at Santa Susana, Calif., during the report period. Maximum firing time for the short-duration tests was three seconds.

LAUNCH OPERATIONS DIRECTORATE ESTABLISHED*

NASA has established a Launch Operations Directorate (LOD) at Marshall Space Flight Center under the Office of Launch Vehicle Programs. LOD will launch most NASA rocket vehicles as well as three Army vehicles -- Redstone, Pershing, and Jupiter. The Directorate will also provide support for other rocket vehicle programs.

* See also Chapter 16, Organizational Developments, p. 193.

Creation of the new directorate, which became operative on July 1, 1960, should increase reliability in launching and testing and should facilitate standardization of facilities and ground support equipment.

LOD Responsibilities

LOD has responsibility for launching Juno II, Thor-Agena, Atlas-Agena, Atlas-Centaur, and Saturn. The Directorate supports launchings of Project Mercury rocket vehicles as well as Delta, Scout, and Atlas-Able.

NASA decided that any launch vehicle program already assigned prior to LOD's establishment, should be left as assigned rather than risk disruption by transfer to LOD. Therefore, Project Mercury rocket vehicles are launched by the Mercury Project Group of Goddard Space Flight Center; Delta is launched by the Goddard Delta Field Project Branch; Scout is contractor-launched, as is Atlas.

Launch Vehicle Facility Status

A master plan for NASA technical facilities at AMR has been developed for all programmed NASA launch vehicles and spacecraft. The plan takes maximum advantage of a centralized area in the southern part of the AMR industrial area at Cape Canaveral. The NASA Industrial Area is composed of hangars for vehicle assembly and checkout, buildings for assembly and checkout of spacecraft, office space, laboratory space, shops, storage and supply issue buildings. As a safety measure, the area is separate and remote from the vehicle launch areas.

The area will provide support facilities to meet NASA's program for the next decade as well as to fulfill NASA's commitment to the Defense Department for carrying through to completion the Redstone, Pershing, and Jupiter development projects. A similar plan will cover PMR launchings.

Program Facility Status

A summary of launch operations facilities and status follows:

Scout: Complete launch facilities have been constructed at Wallops Station including a blockhouse servicing two launch pads, plus ground support equipment.

Another launch facility will be constructed at PMR. A Navy-funded blockhouse, now under procurement, will be used. NASA will fund the launch pad, launcher, service tower, and ground support equipment. Construction will start in mid-1961.

Delta -- All Deltas will be launched from AMR where facilities are available for the program. Complex 17 was modified so that both Pads A and B could handle either the NASA-Delta, Navy-TRANSIT, or the Advanced Research Projects Agency COURIER vehicles. (This back-up capacity was financed jointly by ARPA and NASA.)

Thor-Agena B -- Thor Pads 4 and 5 at Lompoc, Calif., have been assigned to this program. Already instrumented for the Air Force DISCOVERER program, these pads will require little additional instrumentation to accommodate NASA spacecraft. Additional service structures, however, will be required.

Propulsion and Nuclear Energy Applications for Space

ENERGY - KEY TO SPACE EXPLORATION

By far the most important requirement for advanced space-craft is design and construction of more powerful launch vehicles and propulsion systems. To meet demands of heavier payloads and more complex missions, NASA is attacking this problem from many angles -- liquid propellants, solid propellants, and nuclear and electrical propulsion systems.

LIQUID-PROPELLANT ROCKET ENGINES

At present, liquid propellants are still most important in the NASA program. Practically all major launch vehicles, except Scout, employ kerosene and liquid oxygen, a relatively low-energy propellant-oxidizer combination. However, NASA is developing engines using a higher energy combination, liquid hydrogen and liquid oxygen. Such engines will greatly increase payload and mission capabilities, since they will give a specific impulse* more than 25 percent higher than that of the present kerosene-liquid oxygen mixture.

H-1 Hydrocarbon-Oxygen Engine

The H-1 rocket engine, a 186,000-pound-thrust unit based on the Thor design -- modified to provide greater simplicity and reliability -- uses liquid oxygen and hydrocarbon (kerosene) as propellant. Eight H-1 rockets will be clustered in the first stage of the Saturn vehicle to produce 1.5-million pounds of thrust, four times that of the Atlas, the most powerful single U. S. rocket today.

* A term frequently used in evaluating the performance of a rocket propellant; the number of seconds one pound of propellant mass will produce one pound of thrust. The liquid-hydrogen-liquid-oxygen combination will give a specific impulse of something more than 400 seconds, in comparison with less than 300 seconds for the kerosene-liquid oxygen mixture.

A total of 126 H-1 engines will be procured for testing various changes in the design and for use in Saturn vehicles. The contractor is the Rocketdyne Division of North American Aviation, Inc., Canoga Park, Calif.

Tests of Clustered Engines -- A series of cluster-firing tests (using engines capable of 165,000 pounds of thrust) have been made, starting with two engines and progressing to the full eight, the latter producing approximately 1.3-million pounds of thrust. Subsequent cluster tests will use the uprated 188,000-pound-thrust H-1 engine.

Chief problem in development arises from possible engine component malfunctions as a result of hot exhaust gases seeping into the engine compartment. Specially designed devices called "vehicle boattail closures" to prevent this seepage have been coated with heat-resistant materials and tested. Several engine components are now being redesigned to withstand higher operating temperatures.

Strength and Reliability Requirements -- The higher thrust requirement of the H-1, in comparison with the Thor engine on which it is based, has resulted in an effort to increase the mechanical strength of several engine assemblies. Foremost among these has been the propellant pumps and turbines in which an extremely narrow margin of safety exists when the engine is operated at its full thrust level of 188,000 pounds. The necessity of using eight of these engines in a single cluster has greatly increased the problems associated with reliability and maintenance of the first stage. This is reflected in attempts to integrate engine functions (that is, to have one component perform more than one function), and to avoid situations that will lead to hazardous operation. For example, a simple turbopump cartridge starter has replaced two ground-start tanks with associated fill, vent, and level sensing devices, pressurizing system and quick disconnects.

XLR-115 Hydrogen-Oxygen Engine

The XLR-115 engine, designed to produce 15,000 pounds of thrust, is fueled with liquid hydrogen and oxygen, and will be employed in a cluster of two in the second stage of the Atlas-Centaur vehicle. Pratt & Whitney Division of United Aircraft Corp., East Hartford, Conn., is the contractor.

Turbopump Drive Unconventional -- Both the XLR-115 and its scaled-up version, the XLR-119 (discussed in the next section) utilize an unusual thermal cycle that employs no

separate gas generator system for driving the turbopumps. Instead, the turbopumps are driven by hydrogen taken directly from the nozzle cooling jacket. The hydrogen absorbs enough heat from the propellant passing through the nozzle to develop the power that drives the turbine.

Because of the high performance of liquid hydrogen and liquid oxygen as the propellant combination, the cluster of two XLR-115 engines in the Centaur's second stage will provide the largest payload capacity of any Atlas-boosted vehicle.

Program Generally on Schedule -- The engine development program is on schedule, and the preflight rating test (a static test which qualifies the engine for experimental flight use) is expected in December. Delivery of ground test engines to the second-stage contractor, Convair-Astronautics Division of General Dynamics Corp., San Diego, Calif., was delayed about two months as a result of a failure in the first ground test engine. This, being a parallel effort to the main program, does not appreciably affect the vehicle flight schedule.

Summary of Recent Accomplishments -- The following major milestones were laid during the report period:

- 1) A series of tests was completed, which in run time and number of starts demonstrated the ability of the engine to pass the preflight rating test program.
- 2) The engine was operated successfully under propellant supply conditions very closely simulating actual vehicle operation.
- 3) A critical engine start problem was successfully resolved.
- 4) The first two ground test engines were delivered in August 1960 to Convair for the vehicle systems tests mentioned above.

XLR-119 Hydrogen-Oxygen Engine

An uprated version of the XLR-115 discussed above, the XLR-119, is designed to produce 17,500 pounds of thrust. Uprating is required to handle larger payloads. The thrust level chosen is considered the highest that can be obtained without major changes in engine components.

The uprated engine will be used: 1) in a cluster of four for the second stage (designated S-IV) of the Saturn C-1; 2) in a cluster of two in the second stage of later Centaur vehicles; and 3) in the third stage (designated S-V) of the Saturn C-1.

Pratt & Whitney Chosen -- To meet the schedule for the S-IV stage, the XLR-119 program was initiated with the Pratt & Whitney Division of United Aircraft Corp., contractor for the XLR-115, in August, 1960, by a letter of intent for the first 60-day effort. Meanwhile, negotiations for a final contract were under way.

Early months of the program have been devoted to designing the engine modifications that will be needed and procuring items that require long lead times, so that the rather stringent delivery and test schedule could be met.

Preflight rating tests are tentatively scheduled for completion by December, 1961. First ground test engines are to be delivered to Douglas Aircraft Co., Inc., El Segundo, Calif., the vehicle stage contractor, in July 1961.

J-2 Hydrogen-Oxygen Engine

Development of the J-2, a single-chamber, 200,000-pound-thrust, liquid hydrogen-liquid oxygen engine, was begun at the Rocketdyne Division of North American Aviation, Inc., in September. (For contract details, see Chapter 7, Launch Vehicles and Launch Operations, pp. 82-83.) Clustered, these engines will be used in the second stage of the advanced C-2 version of the Saturn.

F-1 1.5-Million-Pound Thrust Hydrogen-Oxygen Engine

Development continued on the F-1, the giant 1.5-million-pound-thrust single-chamber engine which is being considered for Nova, the next generation vehicle beyond Saturn. The contractor, Rocketdyne Division of North American Aviation, Inc., began work on the project in January 1959 (for details, see NASA's Second and Third Semi-annual Reports to Congress). Using high-energy liquid hydrogen-liquid oxygen propellant, the F-1 may be used in a cluster of four to six units as first stage in the Nova launch vehicle.

Static Tests of Uncooled Thrust Chambers -- During the report period, Rocketdyne continued its program of

short-duration (3 seconds or less) static tests of uncooled thrust chambers. In early runs at Rocketdyne's Santa Susana, Calif., facility, a number of injectors (the devices that feed the propellant into the thrust chamber) did not operate satisfactorily, and test hardware was damaged. As a result, a number of new designs or modifications were built and tested, two of which operated very satisfactorily at the limited thrust levels obtainable on the Santa Susana test stands.

New Test Stand Damaged -- Meanwhile, at NASA's Flight Research Center, Edwards, Calif., work is underway to complete test stand 2A which will be capable of testing the F-1 (using cooled, rather than uncooled, thrust chambers) at its full rated capacity of 1.5-million-pounds of thrust. Unfortunately, the initiation tests were delayed for nine to 14 weeks when the new stand was damaged during a trial run on August 21. A malfunction occurred in the duct leading from the oxygen tank on the test stand to the thrust chamber, as a result of contamination in the oxygen system. The thrust chamber was also damaged. It is expected that the stand will be fired for the first time about the middle of December 1960.

The long-range development plan still calls for a preliminary flight rating test of the F-1 engine early in 1963. It is too soon to determine whether time lost because of the August accident can be made up and schedules met.

Tests of Gas Generator -- A long series of tests on the F-1 gas generator were completed with generally good performance. The only problem was an occasional damaged injector due to overheating. It is being corrected by changes in the injection pattern which will keep the hot gases further away from the injector.

Turbopump Assembly Completed -- The F-1 turbopump was assembled at Rocketdyne's Canoga Park plant and readied for testing at Santa Susana in September, employing the same stand formerly used for thrust chambers. Several tests have been made using high-pressure cold gas to drive the turbine. The desired quantities and pressures were achieved by the pumps.

Thrust Chamber Fabrication Techniques -- A study of the technique of fabricating full-size thrust chambers has been started. This is a serious problem, because the structure is so much larger than any previously built, and the enormous thrust of the engine will make unprecedented demands on materials for strength and resistance to high temperatures.

A 1/10-scale model (150,000 pounds of thrust) has been built using Inconel-X (stainless steel) tubes, assembled with a furnace brazing process.

Advanced Technology -- Liquid Rocket Engines

Plug Nozzle -- Through contract with the General Electric Company's Malta Test Station, Schenectady, N.Y., NASA has been investigating the "plug nozzle" concept for rocket engines (see Chapter 11, NASA's Third Semiannual Report to Congress). Preliminary design of a plug nozzle rocket with 50,000 pounds of thrust has been completed, and much of the necessary test hardware has been fabricated.

Three types of injector (designated Models 1, 2, and 3) are to be evaluated. Two injectors of the Model 1 design have already been completed and given a preliminary check, prior to "hot testing" in uncooled thrust chambers. Injector Models 1 and 2 produced rough burning, while Model 3 demonstrated smooth, stable characteristics. Injector Model 3, which was chosen for all future tests, is a rectangular array of parallel strips which contain the propellant orifices. To assure good propellant mixing, adjacent orifices permit the propellant streams to overlap each other. The complete engine design will be modified according to results of the test program.

Storage of Propellants in Space Environment -- The A. D. Little Co., Cambridge, Mass., is working under NASA contract to learn more about storage of propellants in the environment of space. The work calls for an investigation of the effects of solar radiation, other ionizing forms of radiation, and micrometeoroids on fuels and oxidizers such as liquid hydrogen, liquid oxygen, hydrocarbon, and hydrazine. Possible changes in physical characteristics and performance will be needed to hold down losses of these propellants during space missions. Initial effort has been limited to a survey of the field and preliminary calculations of insulating materials.

Studies of Combustion Instability -- Work on problems of unstable, combustion of liquid propellants (discussed in detail in Chapter 11, NASA's Third Semiannual Report to Congress) has continued. The Marshall Space Flight Center has begun wide-ranging experimental studies, on full-scale engines, in an effort to develop a quantitative rating technique on the relative tendencies of particular types of engines to uneven burning or surges. Such a rating system would be of great value in several ways. Not only would it

increase reliability -- but perhaps even more important -- it would permit engines to be matched more accurately for use in clusters.

Tests of Turbopumped Rocket Engine -- Tests of a laboratory engine (a "breadboard" model, not suitable for flight) employing a turbopump and hydrogen-fluorine propellant were begun by Bell Aerosystems of Buffalo, N. Y., under a NASA contract. This is a program to evaluate the problems involved in the design and operation of a rocket engine using this high-energy propellant combination. The use of fluorine has dictated the use of exceptional materials and designs.

Test results have been encouraging. A thrust chamber capable of producing 7,000 pounds was operated with a high level of performance and no damage to equipment. During some of the early tests, small amounts of propellant leaked out, but the condition was corrected, and later runs were made without mishap.

SOLID-PROPELLANT ROCKETS

NASA is devoting much effort to solid-propellant rocket technology. These propellants have several inherent advantages over their liquid counterparts. They can be stored for extended periods and will still give instant and reliable performance. They use simple operating principles, requiring no complex machinery such as pumps, turbines, flow controls, and valves. They have the advantage of fairly simple firing techniques that handling crews can master quickly.

Generally speaking, these rockets have lower development costs and shorter development times than do liquid systems. Moreover, their designs can be altered at low cost to vary thrust levels and burning times.

Despite the advantages apparent, there is a limiting factor. No ultra-high-energy solid propellants have so far been developed. Except for Scout, NASA's launch vehicles are fueled with liquids, at least in the lower stages. Solid-propellant rockets are finding their chief use in the comparatively small (3,000 to 5,000 pounds of thrust) final stages employed in such launch vehicles as Thor-Able, Atlas-Able, and Delta.

NASA has begun programs to establish the cost advantages inherent in large solid-propellant engines used for

first stages in launch vehicles. The agency is continuing programs in all areas of solid propulsion technology, to improve smaller-engine performance, reliability and versatility.

Scout Vehicle Development

To date, the major NASA application of solid propellants -- other than for upper stage engines and small research rockets discussed later in this chapter -- has been in Scout: a 36,000-pound, four-stage launch vehicle which can place a 150-pound payload in a 300-mile orbit. Scout is the first all-NASA-developed launch vehicle.

The first test firing of a complete Scout vehicle took place at Wallops Station on July 1 (see Chapter 7, Launch Vehicles and Launch Operations, p. 75), only 18 months after contracts were let for its components. Scout was launched by a crew that had no previous experience with vehicles of this size.

Algol -- The Scout first stage, designated Algol (after a fixed star in the constellation Perseus), is the largest solid rocket launched in the United States to date, weighing more than 22,000 pounds. It is 30 feet long, 40 inches in diameter, and develops 103,000 pounds of thrust. Fin-stabilized, it is controlled in flight by jet vanes. The reliability of the Algol stage has been outstanding -- there were no failures during the static firing evaluation program, and performance in the two flight tests have been excellent.

Castor -- The second stage, Castor (a star in the constellation Gemini, named for a "tamer of horses" in Greek mythology) is a modification of the Sergeant rocket having an improved propellant and a larger nozzle. Castor is 20 feet long, 31 inches in diameter, has a thrust of more than 50,000 pounds, and weighs more than 8,800 pounds. It has been used clustered in the NASA Little Joe program that supports Project Mercury. For Scout, Castor is stabilized and controlled by hydrogen peroxide jets.

Antares -- The third stage of Scout, Antares (named after the brightest star in the constellation Scorpio) is 10 feet long, 30 inches in diameter, produces a thrust of more than 13,600 pounds, and weighs about 2,300 pounds. Stabilized and controlled by hydrogen peroxide jets and utilizing lightweight plastic construction throughout, Antares is a scaled-up version of the fourth stage, and is the only engine developed specifically for Scout.

Altair* -- The fourth stage of Scout, Altair (named for a star of the first magnitude in the constellation Aquila, or Eagle) is six feet long, 18 inches in diameter, and weighs about 500 pounds. Used extensively in satellite and other space research applications, this smallest of the four Scout rockets is spin-stabilized and has a 3,000-pound thrust. The efficiency of plastic chamber construction is indicated by the fact that both the Antares and Altair rockets are more than 90 percent propellant by weight.

Sounding Rocket Development

NASA's sounding rocket program is under technical management of the Propulsion Office at Headquarters; the Goddard Space Flight Center is responsible for aerodynamic design, integration of payloads, and flight test firings at Wallops Station.

Sounding rockets are employed by NASA to supplement satellite and probe investigations in aeronomy (study of the chemistry and dynamics of gases in the earth's atmosphere), ionospheric physics, energetic particles and fields, galactic astronomy, and solar physics. (Progress in these areas during the period is detailed in Chapter 4, Scientific Satellites and Sounding Rockets.)

Under development is a series of reliable, fairly simple launching rockets to carry relatively small payloads to altitudes below 200 miles. The first two of the series, designated "Arcon" and "Iris," were originally Navy projects, transferred to NASA early in 1959. The Atlantic Research Corp., Springfield, Va., is contractor for both rockets.

Arcon** -- The Arcon development program was completed in 1959 and three flight tests followed during the first half of 1960. Analysis of data from the flight tests indicates that there are aerodynamic problems yet to be solved. A simple redesign of the fins plus a higher energy propellant have been suggested to enable the rocket to climb to

* Altair was formerly known as the X-248 rocket, developed for the third stage of Vanguard. Also used as the third stage of the Able and Delta launch vehicles, it was the first fully developed rocket to utilize lightweight plastic construction throughout.

** Full description and technical specifications of Arcon are in NASA's Third Semiannual Report to Congress.

its design altitude of 70 miles. In the flight tests, it rose no higher than 52 miles because of unanticipated air-drag effects upon the structure.

Two Arcon rockets have been stored for six months at 120°F. at Dahlgren Navy Proving Ground, Va. This is equivalent to two years of storage at room temperature. The heat accelerates aging and is a relatively quick way to assess storage life. One rocket has been removed and studied for evidence of deterioration, and is being readied for static testing. The second Arcon will be removed and studied after it has been subjected to a full year of heat storage.

Three more Arcon vehicles are available for flight test, but a specific schedule has not been set.

Iris* -- On July 22, NASA conducted the first flight test of the Iris sounding rocket at Wallops Station, after a series of static tests during which no failures occurred. Equipped with a 150-pound payload of instruments to record data on its performance (acceleration, rotation, stability, ability of the nose cone to withstand aerodynamic loads and heating, etc.), the rocket reached a 140-mile altitude. It plunged into the Atlantic Ocean about 210 miles east of Wallops. Performance of the main and auxiliary rockets was satisfactory in all respects.

The second and third flight tests, which will complete the development program, will be held later in 1960.

Eleven Types Employed or Planned -- At present, NASA plans to limit its sounding rocket types to 11 and to increase their reliability by frequent firings. The following rocket systems are in use, being developed, or being considered:

* Full description and technical specifications of Iris are in NASA's Third Semiannual Report to Congress.

Rocket	Payload Weight (lbs.)	Design Vertical Altitude (miles)
* Aerobee 100	70	80
* Aerobee 150 and 150A	150	150
* Aerobee 300	50	300
*** Argo E-5	50	600
* Argo D-4	50	800
* Argo D-8	130	1,300
** Arcon	40	55
** Iris	100	180
**** Nike-Asp	50	150
* Nike-Cajun	50	100
*** Skylark (British)	150	150

* In use
 ** In development
 *** Contemplated
 **** Firings suspended

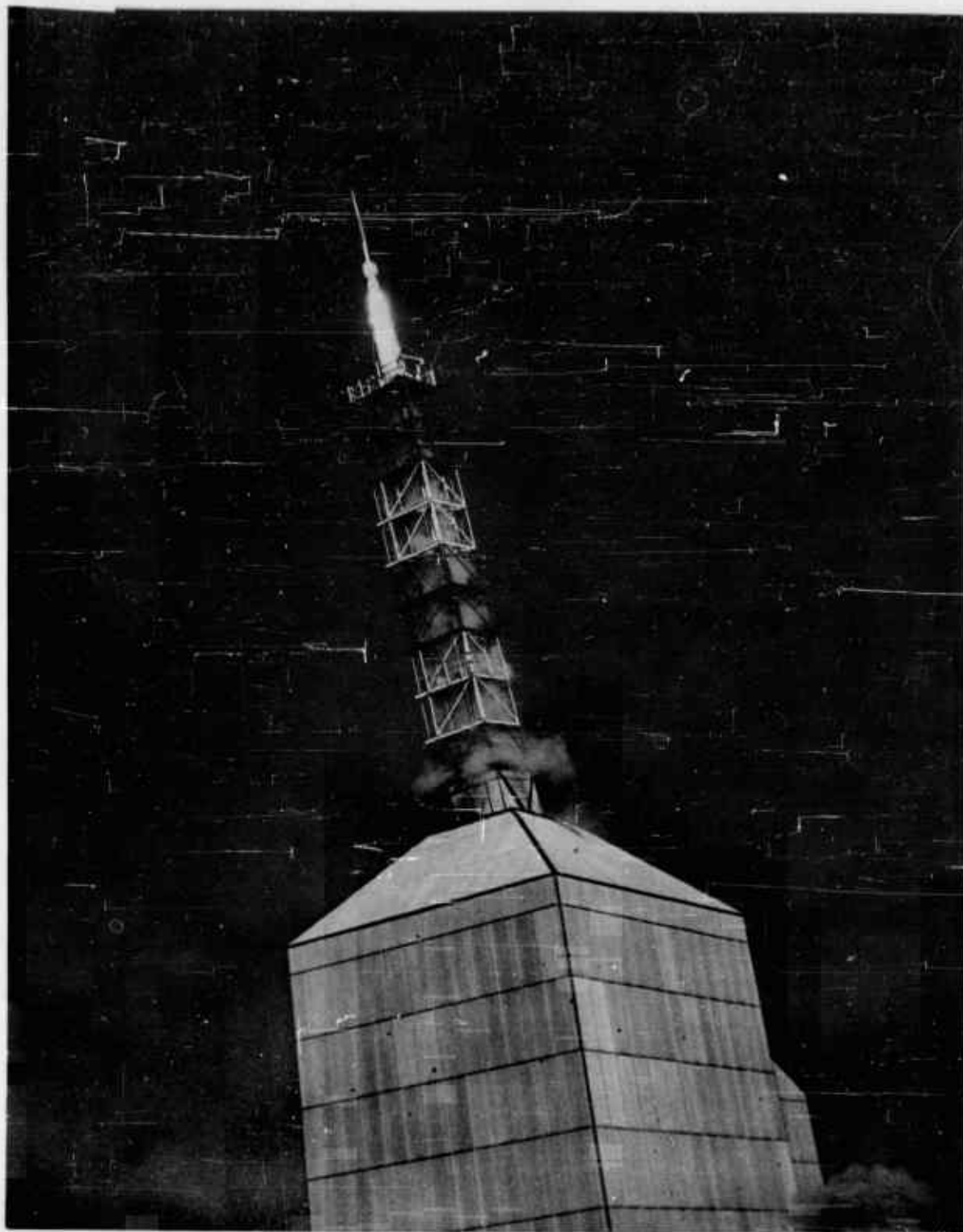
Nike-Asp Flights Suspended -- All flights of the Nike-Asp sounding rocket have been postponed indefinitely because of continued malfunctions in the Asp rocket (see Chapter 4, Scientific Satellites and Sounding Rockets, p. 40).

High-Performance Rocket Engines

During the period NASA let a number of new contracts to develop high-performance rocket engines, and work continued on similar, existing projects:

1) Upper-Stage Rockets -- extension of contract with Grand Central Rocket Co., Redlands, Calif., to develop an experimental rocket engine with a very high proportion of weight of propellant to that of inert parts.* Extension will allow five more static firings, to be followed by a series of reliability firings. The extension was granted

* For earlier progress, see NASA's Third Semiannual Report to Congress, Chapter 11.



NASA's new IRIS sounding rocket roars from its launch tower at Wallops Station, Va., during a test flight on July 22.

after good results were obtained with the third experimental engine during the period; two previous engines had failed soon after ignition.

2) "Nozzleless" Rocket* -- new \$25,000 contract let to Grand Central to study the performance potential of a rocket engine built without a conventional nozzle. In four static firings these units gave satisfactory performance. An analytical phase is now in progress to indicate potential applications for these unique rockets.

3) Experimental Rocket Engine With Layered Construction* -- the Allegany Ballistics Laboratory, Cumberland, Md., a U.S. Bureau of Naval Weapons facility, continued its investigation for NASA of a concept in which propellant layers of varying burning weights are burned in sequence. Another unique feature of the design is that the rocket is made in two sections which are cemented together prior to firing. A very light plastic case is utilized. Two firings were made during the report period which, although not entirely successful, indicate that the concept is promising. Three more firings are scheduled during the next six months.

4) End-Burning Propellant Charges in Low-Weight Upper Stages -- new contract for \$70,000 let to Allegany Ballistics Laboratory in April. Because end-burning charges have no central perforation, almost all the chamber volume is used, adding efficiency. The particular feature to be studied is that of having a fast-burning propellant in the center of the configuration, surrounded by slow-burning propellant which acts as insulation to protect the lightweight chamber wall. Scale-model tests were made during the report period to choose the appropriate propellants for the fast and slow burning parts of the rocket.

5) Nozzle Cooled by Liquid Metal -- new contract for \$206,861 let in July to Rocketdyne Division of North American Aviation, Inc., Canoga Park, Calif. Calculations show that a nozzle cooled by a liquid metal such as lithium can be lighter in weight -- especially in the larger sizes -- than one using ablation materials or one which absorbs the heat (heat sinks). Initial tests have resulted in determination of the best systems design for coolant distribution, and 3,000-pound-thrust nozzles have been fabricated for tests in late 1960.

* For earlier progress, see NASA's Third Semiannual Report to Congress, Chapter 11.

6) Sounding Rocket Combining Several Advanced Design Features -- new contract for \$129,963 let in August 1960, to Altantic Research Corp., Springfield, Va. About six inches in diameter and weighing about 200 pounds, the new rocket design could increase performance by about 40 percent over that of present rockets of similar design. Design work has been completed and components are on order.

Very Large Solid-Propellant First-Stage Engines

On the basis of studies made last year, NASA let three contracts during the period for definitive studies of very large solid-propellant engines as first stages of launch vehicles.*

Three Contractors Selected -- Aerojet-General Corp., Sacramento, Calif.; Grand Central Rocket Co., Redlands, Calif.; and Thiokol Chemical Corp., Huntsville, Ala.-- were selected from seven firms submitting proposals. They will share approximately \$220,000 for six-month studies which were let in September and which will be carried on concurrently for two specific vehicles.

The first vehicle will be in the one million pound gross weight class, about the same as the liquid-fueled Saturn now under development. (See Chapter 7, Launch Vehicles and Launch Operations, p. 74.) The second (in the Nova class) will weigh about seven million pounds. Both vehicles will have solid fuel first stages and high-energy hydrogen-oxygen upper stages. About half the liftoff weight of each vehicle would be concentrated in the solid-propellant first stage.

Designs will employ existing propellants and materials. Economy and reliability will be basic factors, with realistic estimates to be made for both development and final production costs.

Methods of steering these giant solid rockets will also be studied, and attention will be given to logistics problems and special facilities that may be required.

* The 1959 studies indicated that solid-propellant first stage may be as much as 30 percent smaller and lighter than its liquid counterpart, permitting more weight to be added in the more efficient upper stages and thus greatly increasing the payload capability.

Steering and Velocity Control Studies

The Naval Ordnance Test Station, Inyokern, Calif., is continuing its work under NASA task (see NASA's Third Semi-annual Report to Congress) on the feasibility of steering a solid rocket by injecting gases or liquids into the nozzle exit cone. Initial tests have indicated that the injection of fluid, on command, at different locations within the cone will successfully deflect the exhaust stream and change the directions of thrust. Early in the next report period, tests will be made on engines of flight weight to learn if enough steering force can be developed for such engines as Altair (see p. 95), the 500-pound final-stage rocket of the Scout vehicle. The Bureau of Naval Weapons is participating in this program by supplying three basic rocket engines.

"Steering Package" Concept -- NASA let two new contracts during the period to investigate the feasibility of the "steering package" -- independent solid rocket engines weighing only a small fraction of the basic rocket stage, which would eliminate the need for complex movable nozzles, jet vanes, and other more complicated methods of steering. The two firms were selected from 13 submitting proposals.

The first contract, amounting to \$199,000, was awarded in July to the Allison Division of General Motors, Inc., Indianapolis, Ind.; it is for a concept utilizing a group of four independent, rotating solid rockets controlled by the guidance system.

The second, for \$127,159, was also let in July, to Vickers, Inc., Detroit, Mich.; this one will utilize a single solid-propellant gas generator that exhausts through valving arrangements to a series of fixed nozzles to control direction and roll. Both contractors have completed their designs, let subcontracts for their propellant charges and have completed preliminary firings.

Thrust Modulation -- Work under NASA contract to Acoustica Associates, Inc., Los Angeles, Calif., to determine if thrust can be varied by sound waves (see NASA's Third Semiannual Report to Congress) is near conclusion. Tests to date have shown only small variations in burning rate. One more sequence of firings, which will include several revised design concepts, will be carried out early in the next report period to make a final determination of the feasibility of the concept.

High Temperature Nozzle Materials and Manufacturing Techniques

The Arde-Portland Corp., Newark, N.J., has continued its studies (under a NASA contract initiated in 1959 -- see Third Semiannual Report to Congress) of properties of materials suitable for use in rocket nozzles subjected to very high temperatures.

During this report period, the contractor made high temperature tests of pyrolitic graphite (obtained from Raytheon Mfg. Co., Waltham, Mass., through the cooperation of the Special Projects Office of the Bureau of Naval Weapons), and tantalum carbide. Both materials withstood conditions comparable to combustion at 6,700°F and chamber pressures of 500 pounds per square inch, conditions similar to the most severe encountered in solid rockets today.

Segmented and Tapered Rocket Construction

NASA negotiated a contract for \$148,402 with United Technology Corp., Sunnyvale, Calif., in May 1960, to develop techniques for building very large solid-propellant rocket engines in separate pieces or segments. This will permit shipping by truck, railroad cars or other means of transport that would be unable to carry complete units which might weigh several hundred thousand pounds. Problems under study include selecting efficient, lightweight joints, insulating the joints internally, and fabricating a rocket with a slight taper (three degrees over-all). The purpose of the taper is to generate the same gas dynamic conditions in small units that will later be encountered in much longer, heavier rockets (more sections), thereby minimizing the number of full-scale test required. Work will culminate in static tests of a 3,000-pound rocket engine constructed using these techniques. Designs have been completed and fabrication of the lightweight steel cases (38 inches in diameter) has been initiated.

ELECTRIC PROPULSION

Electric Arc-Jet Engines

For missions in space where long operating lifetimes and high efficiency will be required, NASA is studying electric rocket propulsion systems of several types. One promising system is the electric arc-jet engine, in which a propellant such as liquid hydrogen is passed through an

electric arc and heated to several thousand degrees F. The heated propellant then expands as a gas and is ejected through a rocket nozzle to produce a very low thrust -- a fraction of a pound -- but one of very high jet velocity, and hence, of great efficiency in space where gravitational forces are weak.

1-KW Arc-Jet Engine -- On September 12, 1960, NASA issued a letter contract to the Plasmadyne Corp., Santa Ana, Calif., for a one-year program to develop a 1-kw arc-jet engine for spacecraft attitude-control and stabilization systems. Plasmadyne's proposal was one of 11 submitted in response to an invitation which NASA issued to 27 concerns. Purpose of the \$200,000 contract is to develop an experimentally proven engine to control the attitude of a space vehicle. Specifications require a minimum thrust level of 0.01 pound. Operating from a 1-kw power supply, the engine will have a lifetime of 50-hours continuous operation.

30-KW Arc-Jet Engine -- On April 18, NASA awarded two contracts for a one-year competitive effort to develop a laboratory model of a 30-kw arc-jet engine for primary propulsion of spacecraft. The General Electric Co., Evendale, Ohio, and AVCO-RAD, Wilmington, Mass., were selected from a group of eight firms submitting proposals. The engine, about the size of a standard thermos bottle, will produce about one-half pound of thrust, and will have a continuous operating lifetime of 50 hours. It will require an auxiliary electric generating plant such as the SNAP-8 nuclear system now under development (see pp. 108-109). When finally developed, the arc-jet engine system may be used as the main propulsion unit for raising satellites from low to higher altitudes, and for propulsion of spacecraft on earth-ferry and lunar missions.

During September, both contractors started work, each investigating the critical design problems and pursuing a particular approach to the design of the engine. The critical design problems which must be resolved for attaining maximum energy conversion efficiencies and a compact, simple arc-jet engine are: 1) engine cooling; 2) materials; 3) propellant storage and feed; 4) engine start; 5) energy losses; and 6) electric arc stability.

Ion Engines

Ion engines, like arc-jet engines, produce no combustion. A stream of atoms, usually from an alkaline element such as cesium, is passed through a hot electrode (usually

of tungsten), which strips an electron from each atom, creating a positively charged "ion". Ions are collected, focused, and accelerated in a stream, much as electron beams are shot by the "gun" in a television picture tube. Then the ions are recombined with electrons so that the jet is neutrally charged as it is emitted from the engine. No nozzle is required.

Experimental Engine Contract Awarded -- On June 8, NASA announced that it would negotiate a contract with the Hughes Aircraft Co., Culver City, Calif., to build an experimental ion engine. Chosen from 11 bidders, Hughes is designing, developing, and laboratory testing an experimental unit, eight inches wide, producing 1/100 pound of thrust. In September, the Hughes Research Laboratory in Malibu, Calif., began research and development on the experimental engine. If test results are favorable, the engine will be scaled up to a unit having 1/10 pound thrust. The larger engine will operate from a SNAP-8 power supply, and -- after launching by a conventional rocket -- will be the main source for propelling spacecraft on lunar and planetary missions.

Applied Research and Development

Five applied research and development contracts were initiated in September 1960 to obtain information necessary to development of electrical rocket engines:

- 1) Electro-Optical Systems, Inc., Pasadena, Calif. -- experimental program to investigate methods of obtaining heavy, stable negative ions. (The negative ion approach is an alternative to neutralizing a positive ion beam by injection of electrons.)
- 2) General Electric Co., Evendale, Ohio -- theoretical and experimental program on electrical conduction in cesium vapor.
- 3) General Electric Co., Evendale, Ohio -- a mathematical analysis of the paths of electrically charged particles in ion engines.
- 4) Thompson Ramo-Wooldridge, Inc., Cleveland, Ohio -- investigation of ion sources of the arc-type for possible use in ion engines.
- 5) Thompson Ramo-Wooldridge, Inc., Canoga Park, Calif. -- experimental and analytical research and development on porous tungsten ion emitters.

NUCLEAR ENERGY APPLICATIONS FOR SPACE

The nuclear rocket, to which NASA and the AEC have been giving increasing attention during the past year, has tremendous potential for advanced lunar and interplanetary missions. For example, a three-stage Saturn with a nuclear third stage could lift approximately twice the payload of its all-chemical counterpart. For long-range missions with heavy payloads, such a system shows much promise.

In the nuclear rocket, a liquid hydrogen working fluid is heated to a high temperature by passing it through a nuclear reactor. The gas is then accelerated through a nozzle to produce a propulsive jet. The performance obtainable (specific impulse) is not subject to the (chemical and energy) limitations encountered in a chemical combustion rocket. Instead, it is limited only by the maximum temperature at which the reactor core can operate -- the greater the temperature, the greater the specific impulse that can be produced. It may be possible to obtain a specific impulse as high as 1,000 seconds, in comparison with maximum attainable values of somewhere around 400 seconds for the hydrogen-oxygen chemical rocket.

In addition to nuclear propulsion systems, or nuclear heat transfer rockets, another promising application of nuclear energy for space is the nuclear electric generating system. Such a system, for example, might be used either for auxiliary power for instruments, etc., or for producing electricity to power an electric rocket engine (see pp. 108-109).

Nuclear Heat Transfer Rockets

The nuclear heat transfer rocket will consist of the following basic components: 1) a propellant tank, containing liquid hydrogen at approximately -430°F; 2) a pump and its associated drive system, to force the liquid fuel into 3) a nuclear reactor, in which the hydrogen is heated and transformed to hot gas; 4) a nozzle through which the gas is expelled to provide thrust; and 5) a control system.

NASA-AEC Responsibilities -- The nuclear rocket program (Project Rover) is a joint effort of NASA and the Atomic Energy Commission (AEC). NASA is responsible for developing all non-nuclear components, for integrating the nuclear and non-nuclear components into an engine, for supplying the hydrogen propellant, and for integrating the engine into a flight vehicle. AEC is developing the nuclear reactor.

Joint AEC-NASA Nuclear Propulsion Office Established
-- To facilitate joint effort on the nuclear rocket, in September 1960, John A. McCone, Chairman of the AEC, and Dr. T. Keith Glennan, Administrator of NASA, announced the establishment of the joint AEC-NASA Nuclear Propulsion Office (NPO). The new office is consolidating work previously carried out by organizations in each agency. The office, headed by Mr. Harold B. Finger, who has been Chief, Nuclear Propulsion at NASA, is staffed by employees drawn from both agencies. It is located at the AEC Headquarters, Germantown, Md.

A major NASA contribution to the reactor program has been the funding of an AEC contract with the Rocketdyne Division of North American Aviation, Inc., Canoga Park, Calif., to develop a system for feeding the hydrogen propellant into the reactor. Additions were made to the contract during the last six months to provide for developing complete feed systems, utilizing the hydrogen turbopump described in NASA's Second and Third Semiannual Reports to Congress. These systems will be installed at the AEC's Nevada test site and used in the reactor test program. In May 1960, Rocketdyne also began work on a NASA project to develop a liquid-hydrogen-cooled nozzle for use in the reactor test program.

Applied Research -- Programs to provide design data for the nuclear heat transfer rocket program continued under NASA contract in several areas. The Aerojet-General Corp., Azusa, Calif., progressed on studies of dynamic performance characteristics of nuclear rocket systems. The Georgia Division of Lockheed Aircraft Corp., Marietta, Ga., continued developing equipment to be used in determining radiation effects on materials at liquid hydrogen temperatures. Technical Research Group, Inc., Syosset, N. Y., continued investigating a new radiation shielding concept for nuclear powered vehicles. New work initiated under NASA contract during the period included: studies of hydrogen flow in rocket nozzles, by Cornell Aeronautical Laboratory, Ithaca, N. Y.; determination of the properties of hydrogen at high temperatures by the National Bureau of Standards, Boulder, Colo.; and development of methods for calculating requirements for radiation shielding, by the Nuclear Development Corp., of America, White Plains, N. Y.

AEC Test Fires Kiwi-A-Prime Reactor

Early Step in Project Rover -- On July 9, at the AEC test site in Nevada, Kiwi-A-Prime, a nuclear research

reactor designed as an early step* in the Rover program underwent a test run to demonstrate the feasibility of nuclear rocket propulsion. The barrel-shaped device was brought for a few minutes to full power. Hydrogen gas, heated to thousands of degrees as it flowed through the reactor, was discharged to the atmosphere through a nozzle. Another reactor in the series is scheduled for test later this year.**

Nuclear Rocket Test Study

Two Companies Selected for Contract Negotiation -- As part of the early design work on a flight test nuclear rocket, NASA announced in August that it would negotiate cost sharing contracts with the Lockheed Aircraft Corp., and the Martin Co., for six-month studies on the requirements for flight testing of a nuclear rocket system within five years. To assure varied approaches in the study, two contractors were selected from the 12 concerns submitting proposals. The Lockheed effort will be centered at its Missiles and Space Flight Division, Palo Alto, Calif., with nuclear research support from the company's Georgia Division (Marietta, Ga.). The Rocketdyne Division of North American Aviation, Inc., Canoga Park, Calif., will be a subcontractor. The Martin work will be conducted principally at the company's Denver Division, assisted by the Nuclear Division at Baltimore. In addition to the above, unfunded studies are being negotiated with Douglas Aircraft Co., Inc., Santa Monica, Calif., and Convair Astronautics Division of General Dynamics Corp., San Diego, Calif.

To Be "Paper" Study Only -- Prime requirement of the "paper" study (which is entirely mathematical and theoretical, involving no actual hardware or testing) is that the resulting system -- designated the "Reactor In-Flight Test (RIFT) System" -- will supply technical data that can be applied to a useful nuclear rocket stage. The flight test system itself does not necessarily have to be capable of performing useful space missions.

* Kiwi-A, first step in the program, was tested in July 1959. The Kiwi designation stems from the name of a non-flying species of bird native to New Zealand.

** The run was made on October 19, shortly after this report period ended.

Three or More Approaches To Be Considered -- Approaches to the problem of flight testing a nuclear rocket system will include -- but are not necessarily limited to -- the following: 1) a ground launch of the nuclear rocket; 2) a second-stage nuclear rocket, on top of a conventional chemically fueled first stage, tested over a short ballistic trajectory; and 3) an "orbital start" stage in which a nuclear rocket stage would be lifted into earth by a two-stage Saturn vehicle, after which the nuclear stage would be started and tested under conditions simulating those of a long-range mission.

Research and development studies pertaining to the nuclear rocket are in progress at Lewis Research Center and Marshall Space Flight Center, and vehicle preliminary design studies will be contracted to industry in the near future by Marshall Space Flight Center.

Nuclear Electric Power Generating Systems

SNAP-8 Development -- SNAP-8 (System for Nuclear Auxiliary Power), a joint AEC-NASA project, will furnish 30 to 60 kilowatts* of electrical power by taking the heat from a small nuclear fission reactor to heat a liquid sodium potassium alloy in a closed loop of piping that passes through a boiler. This heat is transferred through the boiler, or "heat exchanger," to liquid mercury in a second closed loop of piping, sealed off from the first. The mercury is boiled and the mercury vapor expands through a turbine which drives a generator, much as in a conventional electrical utility generation plant. The use of liquid metals as the "working fluids" permits the use of high temperatures needed to produce electricity in a plant of small size and light weight. In SNAP-8, the goal is an engine weight of 50 pounds for each kilowatt of electrical power at the 60 kilowatt level.

* The SNAP-8 reactor and conversion system will be the first in the SNAP series powerful enough to generate electricity for propulsion as well as serving as the source of electricity for payload instrumentation. (The original design, with one turbine-generator, is intended to produce 30,000 watts of electricity. By coupling two turbine-generators in parallel with one reactor, it will generate 60,000 watts.)

On May 9, 1960, Aerojet-General Corp., Azusa, Calif., began development work under NASA contract to build the power conversion system for SNAP-8 and to integrate the reactor into an operational system. The Atomics International Division of North American Aviation, Inc., Canoga Park, Calif., is building the SNAP-8 reactor, under contract with AEC.

High-Power Reactor Turbogenerator Systems -- Future
NASA plans call for developing higher-power reactor-turbogenerator systems to follow SNAP-8. Now under consideration are systems producing power levels of one million watts, and 20 million watts. This will require new technology based on liquid metal working fluids that can operate at higher temperatures than mercury. Methods will have to be devised for containing metal vapor, for lubricating rotating parts, and for discharging excess heat through massive space radiators.

As a start, a NASA program of applied research is being pursued to learn more about the properties of sodium and potassium at extremely high temperatures. The Naval Research Laboratory has been working on the properties of sodium for NASA. In August, the Battelle Memorial Institute, Columbus, Ohio, started similar work on potassium. Negotiations are in progress on a contract with General Electric Company's Flight Propulsion Laboratory Dept., Cincinnati, Ohio, to study the heat transfer properties of sodium and potassium at temperatures up to 2200°F. In March, the Rocketdyne Division of North American Aviation, Inc., began studies on the corrosion properties of liquid potassium. Pratt & Whitney Aircraft Division, United Aircraft Corp., Hartford, Conn., is continuing work on the measurement of emissivity of radiation materials.

Radioisotope Thermoelectric Generator for Lunar Landing Missions

Compact Auxiliary Power Unit Required -- One of the requirements for lunar landing missions will be a relatively small, compact, long-lived auxiliary power unit for electronics and other instrumentation and equipment. A method giving promise of fulfilling these requirements is the radioisotope thermoelectric generator. This device employs nuclear radiation (usually in the form of alpha particles) given off by certain "hot" atoms to produce electricity. A feasibility study of such a device is being made by the AEC for NASA.

15-Watt Unit Being Considered -- The device under tentative consideration will have a design power output of 15 watts. The power source contemplated is the radioisotope curium-242, an alpha emitter. It is considered promising because: 1) it is a solid, and is thus easier to handle and to protect against the hazards of radioactive contamination than, for example, polonium 210, which is a gas; and 2) it has a fairly long life (its "half-life," or the period of time required to exhaust half its power, is 162 days). Enough curium-242 to produce 15 watts of electrical power will cost about \$60,000.

SECTION IV

COOPERATION AND AGREEMENTS

WITH OTHER NATIONS

International Programs*

TRACKING NETWORK NEGOTIATIONS

Formal agreements for all NASA tracking stations abroad had either been signed or were in final stages of negotiation by the end of September. Agreements for the following were signed during the report period: 1) the Mercury station at Guaymas, Mexico (April 12); 2) the Minitrack station at St. Johns, Newfoundland, Canada (August 24); and 3) the Deep Space tracking station at Krugersdorp, near Johannesburg, Union of South Africa (September 13). The South African agreement also renewed arrangements for the Baker-Nunn tracking camera station at Olifantsfontein and the Minitrack station at Esselen Park, both of which are in the vicinity of Johannesburg.

The United Kingdom gave interim authorizations for construction of Mercury stations on Canton Island (April 6), Zanzibar (April 24), and Kano, Nigeria (April 29), and of the Minitrack station at Winkfield, England (May 16).

SATELLITE APPLICATIONS

International Participation in Echo I Experiment

By advance distribution of technical information on the Echo I passive communications satellite, NASA made it possible for many foreign scientists to take part in the experiment.

The first receipt of a trans-Atlantic transmission from the U.S. employing Echo I as a reflector was reported by the French National Telecommunications Establishment. The first trans-Atlantic voice message via the satellite was received in England. Representatives of the Soviet Academy of Sciences organized a visual tracking program and supplied a number of observations to the U.S.

* Details of the Echo and TIROS satellite experiments, referred to in this chapter, are in Chapter 2, Satellite Applications. Information on other satellite experiments and on sounding rocket launchings is in Chapter 4, Scientific Satellites and Sounding Rockets.

International Cooperation in Second TIROS Experiment

In August, NASA and the U. S. Weather Bureau invited scientists of 21 nations* to take part in the second TIROS weather satellite experiment. NASA will provide orbital data to scientists in foreign countries who could make surface and other observations of weather conditions and synchronize them with satellite passes. This data will be correlated with cloud-pattern photographs transmitted by TIROS II.

Eventually NASA will make all the information available in the World Data Centers that were established during the International Geophysical Year (IGY).

RESEARCH IN SPACE SCIENCES

Argentina

Representatives of the newly established Argentine National Space Committee visited NASA in July to discuss the possibilities of: 1) cooperative space science research, 2) NASA participation in a Pan American Space Symposium to be held in November 1960, and 3) training young Argentine scientists in NASA laboratories.

Australia

The U. S. and Australia have started formal negotiations on a cooperative program for mapping ultraviolet radiation in Southern Hemisphere skies in 1961. NASA would provide sounding rockets and instrumentation; the Australian Department of Supply would launch the rockets and record and analyze data.

Canada

NASA has earmarked a Thor-Agena B launch vehicle for launching a "topside sounder" satellite which is being

* Argentina, Australia, Belgium, Canada, Czechoslovakia, Denmark, France, German Federal Republic, India, Italy, Japan, Mexico, the Netherlands, Norway, Poland, Spain, Sweden, Switzerland, Union of South Africa, Union of Soviet Socialist Republics, and the United Kingdom. Each has a space organization or is a member of the International Committee on Space Research (COSPAR).

instrumented and fabricated by the Canadian Defence Research Board. The satellite will be instrumented to gather data on the portion of the ionosphere extending above the region of maximum electron density -- that is, at altitudes higher than 180 miles.

An agreement extending for five years NASA use of the Fort Churchill launching range in Manitoba, Canada, was concluded on June 14.

Chile

In August, NASA's Goddard Space Flight Center initiated a training program to prepare Chilean technicians for participation in the operation of Minitrack stations at Antofagasta and Santiago. More than half of NASA's tracking stations abroad are entirely or partly staffed by technicians of the country in which they are located.

Italy

NASA and the Italian National Space Commission plan joint experiments in early 1961 to study winds and temperatures in the upper atmosphere. In the experiments, sodium-vapor sounding rockets will be fired from Sardinia.

Japan

During the Second International Space Science Symposium in Tokyo, May 23-28, Japanese and NASA scientists held additional informal discussions on a cooperative space research program. The discussions began in Nice, France, in January 1960 and continued in February 1960, when a Japanese delegation visited NASA Headquarters.

United Kingdom

During the report period, the United Kingdom and the United States were in the process of carrying out a cooperative scientific satellite program. For this undertaking, NASA Scout launch vehicles will be employed to orbit satellites instrumented in Britain.

DISSEMINATION OF TECHNICAL INFORMATION

Explorer VII Calibrations

On May 31, NASA issued the telemetry calibrations of the Explorer VII satellite to members of the Committee on Space Research (COSPAR) and to other scientists abroad, making it possible for them to analyze data transmitted by the satellite. Launched October 13, 1959, Explorer VII has provided significant information on radiation, magnetic fields, micrometeors, temperatures, and weather patterns.

Exhibits, Motion Pictures, and Publications

NASA also disseminates technical information about its activities by exhibits at trade fairs abroad, motion picture screenings at international technical society meetings and film festivals, and technical publication exchange programs with other nations (see Chapter 20, Other Activities, pp. 219-221).

FELLOWSHIPS AND EXCHANGE PROGRAMS

Ten scientists from Japan, New Zealand, Turkey, Italy, Australia, Republic of China (Taiwan), and India were awarded NASA grants for extended study in NASA laboratories under a program funded by NASA and administered by the National Academy of Sciences. As the period ended, NASA was arranging for several foreign scientists -- sponsored by their governments -- to study space technology at NASA laboratories for periods of varying length. This latter program involves no grants.

About 90 NASA officials took part in 30 technical and scientific conferences and consultations abroad during the six-month period. Typical was the International Astronautical Congress at Stockholm, Sweden, August 15 - 19. The delegates heard a recording of the President's message which had been transmitted from California to New Jersey via the Echo I communications satellite.

About 275 foreign scientists, government officials, and representatives of academies and industry visited NASA during the report period. Among them was Dr. A.C.B. Lovell, founder and director of the University of Manchester Jodrell Bank radio telescope facility in Lower Withington, Cheshire, England. In July, Dr. Lovell visited the White House, discussed international space cooperation with NASA officials, and inspected U. S. Government radio telescope installations at Green Bank and Sugar Grove, W. Va.

INTERNATIONAL ORGANIZATIONS

NASA has continued its support of COSPAR through the National Academy of Sciences. Jointly with the Department of State, the agency gave informal assurances of cooperation to scientists of 10 European nations* which are considering a space effort modeled on CERN (Centre European pour la Recherche Nucléaire). In addition, NASA scientists participated in the Advisory Group on Aeronautical Research and Development of the North Atlantic Treaty Organization.

NASA continued its preparations for the International Conference on the Peaceful Uses of Outer Space. The United Nations General Assembly Resolution (see Chapter 9, International Programs," Third Semiannual Report) stipulates that the conference will be held under United Nations auspices.

* Belgium, Denmark, France, German Federal Republic, Italy, the Netherlands, Norway, Sweden, Switzerland, and the United Kingdom.

SECTION V

ADVANCED RESEARCH PROGRAMS

NASA is pursuing a vigorous, basic aeronautical research program, much of it applying to -- and blending with -- the problems of space flight, to which extensive fundamental research is also being devoted. The agency's research centers concern themselves with everything from the pure research of gas flow phenomena, to applied research on aerodynamic* heating, stability, and control of a variety of advanced vehicles; flight mechanics**; chemical and metallurgical studies of materials; electrical, nuclear, and chemical propulsion systems; and many other lines of research.

Other areas discussed in this section include support of vehicles, such as the X-15 experimental research airplane, NASA's Project Mercury capsule, and the USAF Dyna-Soar orbital glider. Research is also continuing to support some of the ballistic and interceptor programs of the Department of Defense.

The final chapter in the section describes research equipment, building, etc., recently constructed or being constructed for use in the program.

Projects which NASA advanced research supports appear in other sections of this report.

Background information and earlier research in these areas were detailed in NASA's First, Second, and Third Semiannual Reports to Congress.

* Aerodynamic research embraces the phenomena of gas motion and the flight of vehicles through the atmosphere of the earth and other planets.

** Flight mechanics deals with motions of vehicles in atmospheres and the near-vacuum of space, and with the control of these motions either automatically, or by a pilot. It also includes guidance and navigation problems of terrestrial and space flight.

Research Primarily Supporting Aeronautics Activities

STABILITY AND CONTROL OF AIRCRAFT

Research on VTOL/STOL Aircraft

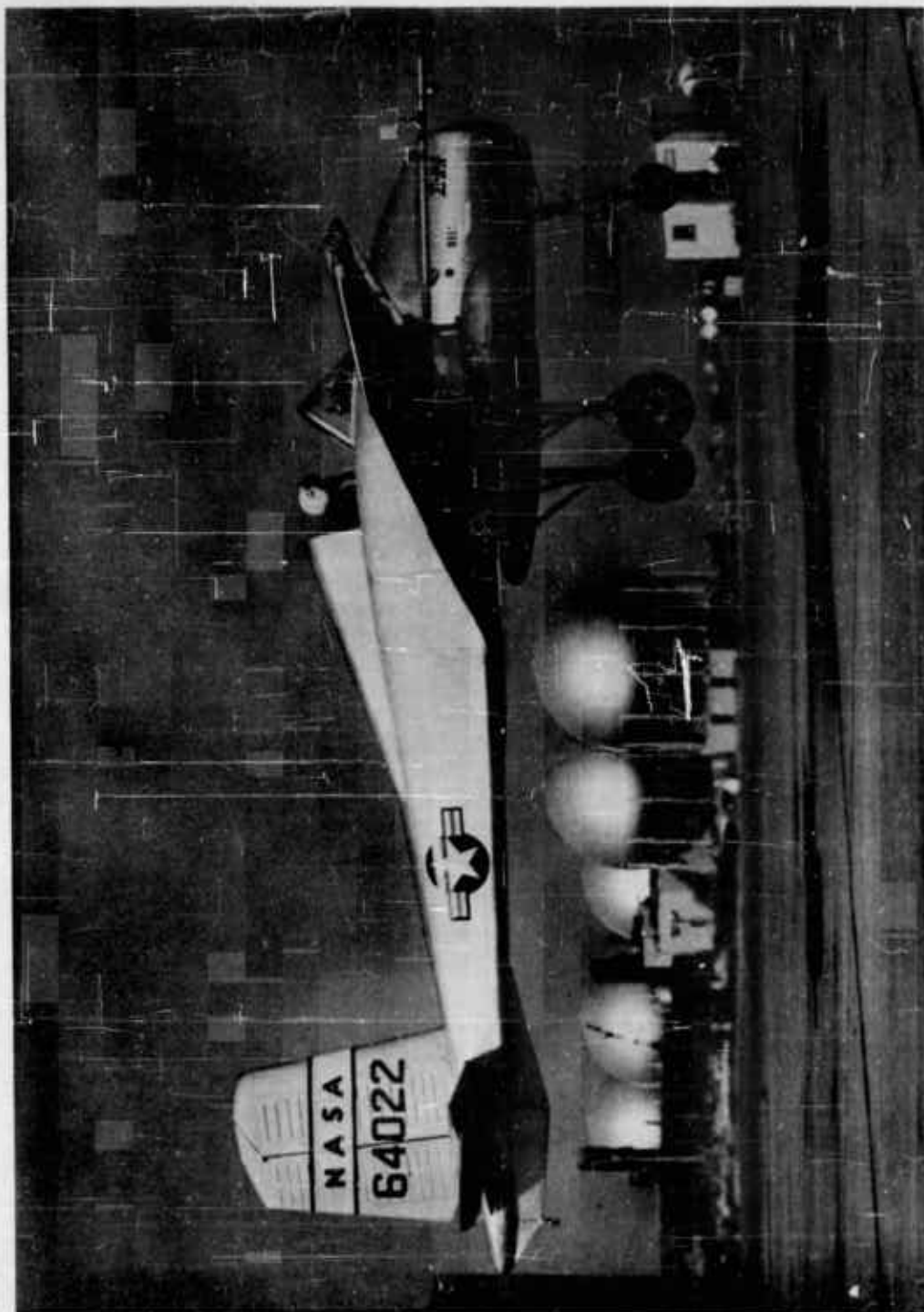
Vertical Take-Off and Landing (VTOL) and Short Take-Off and Landing (STOL) aircraft are special-purpose vehicles which take many basic forms, each with advantages and disadvantages for specific missions. Further progress in developing such aircraft depends, first, on defining the special qualities that are most useful, and, second, on assessing which of the proposed types can best achieve the qualities desired.

Research is going forward at both the Langley and Ames Research Centers. Langley flight studies are continuing with a tilt-wing VTOL aircraft to learn more about its flying qualities. One relatively minor modification -- drooping the leading edge of the wing -- has appreciably improved the performance of this aircraft. Flight tests have been augmented by wind tunnel studies to assess the value of possible further modifications.

At the Ames Research Center, NASA work based on flight tests, wind tunnel experiments, and ground-based simulators, has evaluated flying and performance requirements of STOL and VTOL aircraft. This study is useful for comparing various concepts and types, and it also pinpoints areas where additional research is needed.

Tests With Flight Simulator -- One valuable research tool to be used in continuing the flying requirements study is the deflected-turbojet X-14 airplane, modified to enable simulation of the characteristics of various other VTOL/STOL aircraft. Equipped with variable stability, variable damping, and variable control, this machine can be used to check many types of aircraft during any portion of flight, from hovering, through transition phases, to full speed flight.

The Lifting Fan Engine -- In the Ames 40- by 80-foot wind tunnel, a study was made of a new lifting-fan engine (built by the General Electric Co.) in a full-scale model aircraft. The fan is installed in the body (fuselage) in such a way that the aircraft can take off and hover by



X-14 variable stability aircraft, capable of simulating many VTOL/STOL characteristics, in hovering flight.

directing fan discharge downward. The aircraft flies forward by directing part of the discharge to the rear by means of controllable louvers.

Serious control difficulties were expected, particularly during transition from hovering to forward flight; however, wind tunnel tests indicated that balance can be maintained in all phases of flight and forward speeds.

Further study of the fan-in-fuselage arrangement is planned; preparations are also being made to investigate a related concept, the fan-in-wing.

Jet-Powered Turbofan VTOL Airplane -- During the report period, a model of a jet-powered turbofan airplane was tested in a Langley wind tunnel to determine its aerodynamic characteristics with power on and power off. An aircraft utilizing this concept can make a vertical or short take-off, and cruise at high subsonic speeds. (The jet nozzles can be swiveled or tilted from horizontal to vertical through a 90-degree arc. The 90-degree position is used for vertical take-off and landing and the horizontal for high-speed subsonic flight.)

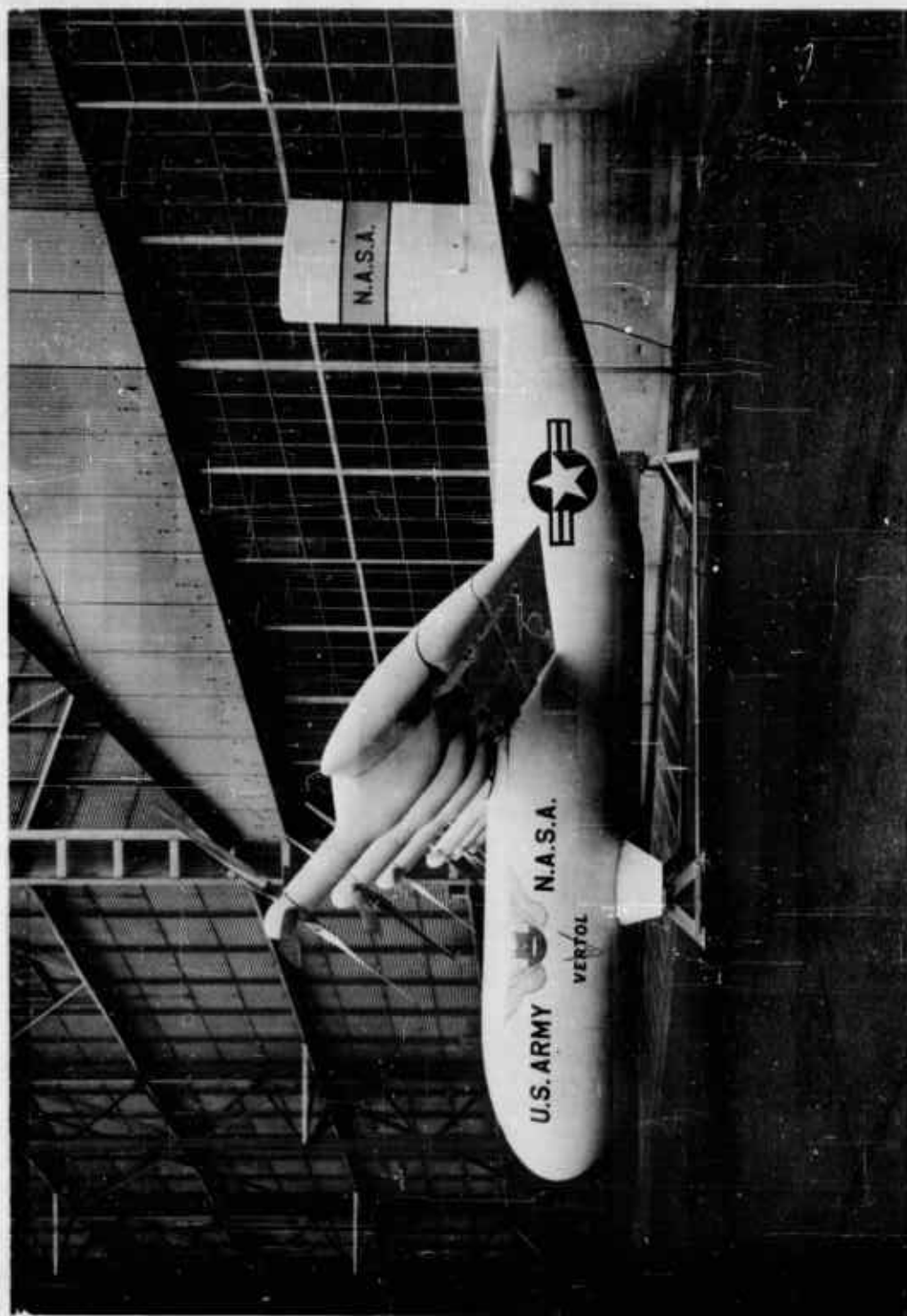
The model tested has two large air-intake inlets, one on each side of the engine, and four jet nozzles, two on each side of the fuselage under the wings. One exit on each side is near the leading edge, or front portion of the wing, the other near the trailing, or rearward edge.

In the "power off" tests, air from the wind tunnel was blown into the inlets and exhausted through the exit nozzles. Then "power on" operation was simulated by injecting into the internal ducting system the jet exhaust materials produced when the propellant (a 90 percent mixture of hydrogen peroxide) is burned. The hot jet exhaust simulated the nozzle flow characteristics of a turbofan engine. The nozzles were canted or tilted downward 1.5 degrees to simulate high-speed cruising conditions.

AERONAUTICAL PROPULSION SYSTEMS

Inlets of Jet Engines

Theoretical and mathematical studies, coupled with experimental research in laboratories and wind tunnels, are being carried on at Langley to determine the best designs and dimensions for air inlets of jet aircraft engines. Often referred to as "air-breathers," these engines rely on oxygen in the air as combustor to burn the fuel. The design of the



Large-scale model of a V/STOL research aircraft which is being tested in the Full-Scale Wind Tunnel at Langley Research Center, Hampton, Va.

air inlet, or opening through which oxygen is introduced to the engine, becomes critical at hypersonic speeds*.

Design Criteria Established -- A number of items must be taken into account in order to achieve the best compromise solutions to problems involved -- for example: 1) There must be as large a difference as possible between the thrust, or force, of the jet exhaust as it presses through the chamber and out the nozzle, and the external drag on the body of the aircraft. 2) The inlet must be of the minimum length and weight required to carry out its function properly. 3) The inlet must be kept cool enough to hold its shape and strength under intense aerodynamic heating, but cooling should be held to the minimum required. 4) The design must be simple, requiring the fewest possible changes in size and shape ("variable geometry") for efficiency throughout the speed range. 5) Inlet structures must be designed to withstand the extremely high pressures (as well as temperatures) encountered in hypersonic flight.

Data derived from these investigations can be applied alike to the design of long-range passenger and transport aircraft.

Earlier studies of aerodynamics and engine capabilities of hypersonic jet aircraft have indicated that a well-designed transport, capable of cruising at Mach 6 (or about 4,100 mph**), should be able to fly half the distance around the world without refueling. However, a jet propulsion system must be developed that can operate efficiently at very high temperatures. At Mach 6, the air entering the inlet would be at about 2,600°F. and the gas combustion at about 4,800°F. Thus, one most difficult design problem is to develop cooling techniques and heat-resistant materials for the air inlet and all other components of the jet engine.

Wind Tunnel Studies -- Wind tunnel studies of air intake patterns and the way they are affected by inlets with highly cooled walls and blunt surfaces*** on portions facing the air stream are being evaluated at Langley. Data are being

* More than five times the speed of sound (which varies with altitude and temperature, ranging from about 760 mph at sea level to about 650 mph in the stratosphere).

** Mach 6 is the maximum cruising speed under serious consideration at present, owing to greatly increased aerodynamic heating problems at higher speeds.

*** Blunt shapes that are not streamlined reduce the local heat transfer to exposed surfaces.

correlated as closely as possible with effects that will be encountered during actual operation at high temperatures.*

A number of basic conclusions have been drawn from these studies. For example, a pipe-like, or duct-like, three-dimensional inlet, in which the air is compressed internally as it passes through, appears to hold special promise for hypersonic applications. It may be designed to take maximum advantage of radiation cooling, to produce efficient performance, and at the same time to keep outer-surface drag to a minimum. The structure can be made short and compact through use of simple, circular ducts. Models of this type will be tested experimentally in wind tunnels.

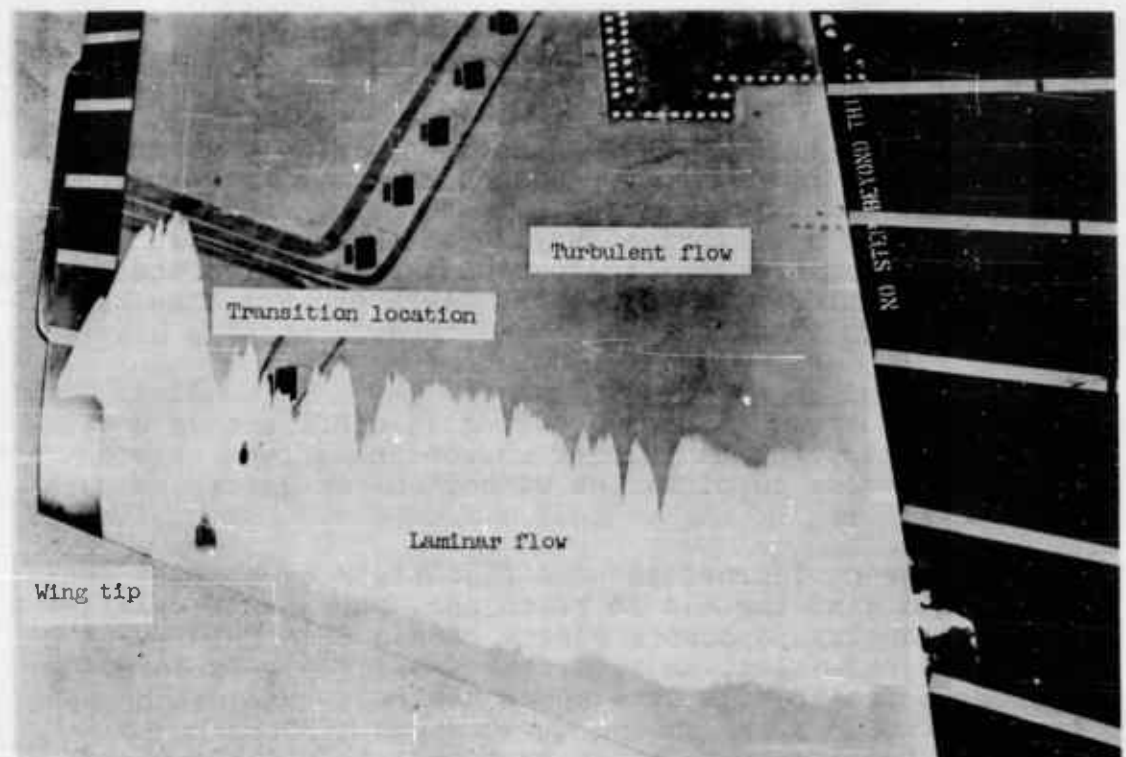
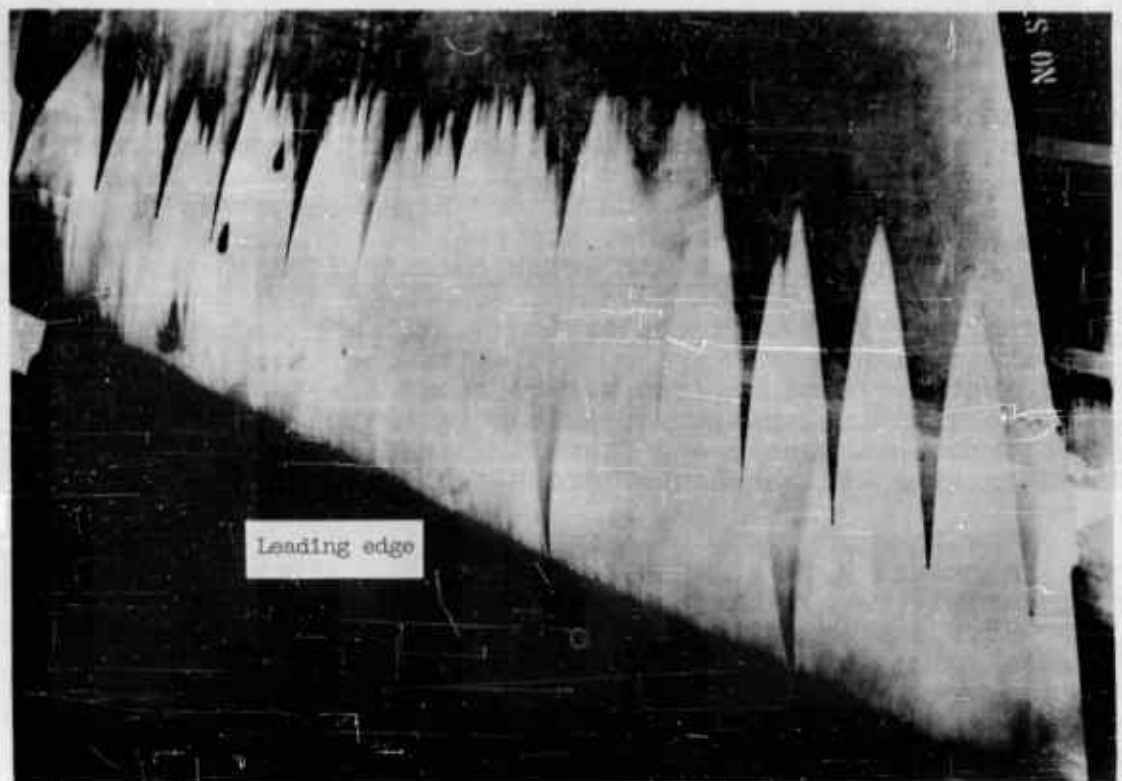
Another design, called the "spike" inlet because of its shape, is undergoing test. Data on air flow along the spike have been obtained at temperatures ranging up to 3,700°F. Pressure distributions measured along the surface of the spike differed markedly from those expected according to theory. Apparently, this was caused by the effect of the blunted tip of the spike, and the viscous effects of the boundary layer.** No difficulty was encountered in cooling the test model; changes in the air temperature from 1,900° to 3,700°F, had little effect on air flow.

Other Studies to Improve Jet Engine Performance -- Several other studies were carried out at Langley to improve the over-all characteristics of jet engines at speeds and altitudes other than those for which they were designed. Tests were performed in the 9- by 12-inch "blowdown" tunnel, in which stored compressed air is suddenly released and expands through a test section. This supersonic stream of cold air passes through a scale-model suspended in the tunnel. Three speed ranges were investigated: Mach 1.93; Mach 2.55; and Mach 3.05.

One model engine housing tested had a streamlined terminal fairing surrounding the nozzle exit. Efficiency was found to be only slightly lower than that of conventional nozzle and afterbody combinations without streamlining between the after portion of the vehicle and exhaust nozzle. Use of

* Much is being learned about air inlet problems with conventional wind tunnels in which the air flow is relatively cool. Langley is also making a specialized study of a conventional inlet, using a heated-air facility in which temperatures as high as 4,000°F can be obtained.

** An aerodynamics term for an extremely thin layer of air next to the surface of a body moving through the atmosphere. The flow in the boundary layer may range from laminar (smooth) to turbulent (rough).



Aerodynamic flow patterns outlined as a result of tests at Flight Research Center Edwards, Calif.: Induced transition (upper); Natural transition (lower).

terminal fairings may improve performance at near-sonic speeds without causing much performance loss at the supersonic speeds for which the engines are designed.

AEROELASTICITY AND DYNAMIC LOAD PROBLEMS

Variety of Studies in Progress

With increasing size, aircraft and spacecraft structures become more and more flexible. The materials used are strong, but panels and "skin" are often relatively thin. Thus, external stresses or "loads" readily deform or bend them.

Although much of this technology was originally developed for aircraft, it can also be applied to spacecraft. Other problems, relating to hypersonic aircraft or to extremely large launch vehicles, are comparatively new. Studies are continuing in such areas as gust loads, wind shear*, maneuver loads, sonic boom and other noise problems of hypersonic aircraft, fatigue and breaking down of structures as a result of intense noise and engine vibration, self-induced vibrations or oscillations called "flutter", fuel sloshing, landing gear and brake problems, especially on slush- or water-covered runways, and other external stresses and loads.

Blast Loading Studies -- A facility for investigating aerodynamic loading conditions caused when a missile warhead explodes near an airplane in flight was recently placed in operation at Wallops Station, Va., by Langley Research Center. A relatively large model (six-foot wing span) is mounted in the flow field from a shock tube**. At a pre-set time, an explosive charge is detonated in the tube, sending a blast

* The effect of wind currents moving at different velocities at different strata or altitudes, or the effect of wind currents moving in different directions at different altitudes.

** The shock tunnel providing the flow field is a simple tube, 10 feet in diameter and 80 feet long, permanently sealed at one end. The opposite end is closed by a thin metal diaphragm. For a given time, the tube is pressurized and heated to produce the flow speed desired. The diaphragm is then ruptured, releasing the trapped air to expand and flow from the tube at the desired speed and temperature. The explosive is detonated so that the blast wave strikes the model during the "steady state" portion of the flow issuing from the tube.

wave through the stream of air to strike the model at a controlled angle. Special fast-response pressure cells, designed by NASA scientists, are mounted on the model to measure the resulting aerodynamic loads.

A preliminary test made recently showed that the present arrangement can measure the important initial phase of the blast loading. The manner in which the blast wave first enfolds the model can be determined, as well as subsequent development of the aerodynamic loading.

Rotary Wing Dynamics -- Helicopters and VTOL aircraft are subject to numerous vibration and dynamic loads. Two analytical studies are under way to reduce severe vibrations associated with rotocraft. The first study concerns high vibration levels that result when the rotors turn at a speed having the same frequency of vibrations as that of the aerodynamic forces working against the blades. Results of the study show that this effect could be largely prevented by using flapping joints or hinges, spaced at carefully chosen intervals along the blade span. These would permit blade frequencies to be controlled over a wide range of rotor speeds.

The second study deals with the mechanical instability of rotors. As rotational speed builds up, rotor components often develop undesirable oscillations. The study showed that whenever new degrees of freedom are included in the system -- for example, those resulting from mounting rotors on a flexible wing structure * -- mechanical instability is likely to result.

Studies of Flutter in X-15 Fairing Panels -- In the Unitary Plan Wind Tunnel at Langley, experimental studies were made of vibrations ("flutter") of panels used for the X-15 experimental airplane**. The tests showed that flutter could be prevented by adding a small stiffener to the panels. Thirty-eight panels to be used in the program were so modified. Flight tests have revealed no further trouble from the source.

Measurements of Severe Storm Turbulence -- The effect of severe storms and turbulent stresses they impose upon

* This problem is heightened because of the inherent difficulty of checking or restraining ("damping") the bending and turning motions of wing structures.

** The flutter was detected in early flights at conditions well below the maximum capabilities of the X-15; as a result it was not dangerous or destructive, although it could have been so at higher speeds.

transport aircraft has long been a subject of NASA study. Langley Research Center, in cooperation with the U.S. Weather Bureau, is using an instrumented Air Force jet-propelled airplane to fly into storm centers and take detailed turbulence measurements. This activity is called the "National Severe Local Storm Research Project."

During May and June, the airplane made flights totaling almost a thousand miles into the centers of thunderstorms. Data obtained are being evaluated, and will supply much information that can be useful in future airplane structural design and operational problems. Results are also being compared with radar and other storm measurements taken by the Weather Bureau. Additional studies are in progress to relate turbulence intensities to the temperature, location, and other characteristics of air masses in which the measurements were taken.

High-Altitude Atmospheric Measurements -- NASA is cooperating with other agencies -- including the Army, Navy, and Air Force -- in firing fairly small, inexpensive sounding rockets on a regular schedule from several locations in the North American continent, including Wallops Island, Cape Canaveral, Pt. Mugu, Calif., Ft. Greeley, Alaska, and others. The rockets are instrumented to obtain information on winds, temperatures, and air densities at altitudes of 18 to 48 miles. The information is used in designing and operating launch vehicles, meteorological studies, and for a better understanding of the laws of the earth's atmosphere.

AERONAUTICAL STRUCTURES

High-Temperature Structures

Research in the field of structures resistant to high temperatures embraces a wide variety of flight vehicles -- supersonic and hypersonic aircraft, entry and landing vehicles, missiles and launch vehicles. Much of the research is basic, with both aeronautics and astronautics applications.

Studies of Heat Transfer Through Sandwich Panels -- Sandwich panel construction (a commonly used strong, lightweight layer-like arrangement) is applicable to flight vehicles of all types. A study of heat transfer properties of such structures has recently been completed at Langley. Two types of sandwiches were tested -- honeycomb core and corrugated core panels -- to determine structural performance and to predict insulation and air conditioning requirements for vehicles made of these materials.

Data obtained took into account the thermal conductivity of the panels in relation to geometric factors (size, thickness, shape, etc.), the properties of the construction materials used, and the surface temperatures. At very high surface temperatures, much more heat is transferred through the panel than would be expected from the conducting properties of the metal. Experimental checks on these calculations have been made with small test specimens. Larger panels will be tested in special thermal conductivity apparatus now in final stages of design.

Compressive Strength of Sandwich Panels -- Further studies of sandwich panels have been concerned with their resistance to compressive forces when subjected to widely different temperatures on the two faces -- a condition frequently encountered when a vehicle is subjected to aerodynamic heating. Small stainless-steel specimens (honeycomb core and corrugated core) were heated to different temperatures on their opposite faces; temperature differences ranged from 200° to 600°F. Maximum test temperature was 1,200°F. The experimental data showed good agreement with the calculated strengths.

During the report period, other related experimental work at Langley included tests of corrugated panels and "shear webs" (very strong, light, spotwelded structures fabricated from a heat-resistant nickel alloy), and studies of resistance to creep* of aircraft with very long lifetimes (30,000 hours is frequently considered a minimum goal for a supersonic transport, and most of this will be spent at high temperatures).

Forces and pressures were measured with the model head-on to the airstream, and at various angles of attack (nosing up at angles of 0 to 20 degrees) and sideslip (tilting at angles of -5 to plus 10 degrees).

The model was found to be unstable along its longitudinal (stem-to-stern) axis at speeds up to Mach 0.90. Several minor modifications were made to reduce this instability (called "pitch up"), the most promising of which seems to be slanting the horizontal part of the tail assembly at a negative dihedral angle (sloping downward from the center of the assembly to the tips).

The effects of the jets on the handling characteristics of the airplane were generally small. No particular problem due to jet interference (the flow of jet exhaust around control surfaces of the plane) was indicated.

* The metallurgical term for plastic flow of a material under constant stress. The effect increases rapidly with mounting temperatures.

Research Primarily Supporting Space Activities

ASTRONAUTICS RESEARCH

Control and Guidance of Space Vehicles

Precise Attitude Control for Satellites -- For many missions, it is necessary to control the attitude of a spacecraft with great precision. In the case of an orbiting astronomical observatory, for example, the telescope must be pointed with an accuracy of 0.1 second of arc, and this attitude must be held for long periods. The problem of maintaining accuracy is aggravated by the disturbing forces that affect the satellite, such as the earth's gravitation, solar radiation, and atmospheric drag.

Theoretical and experimental studies of attitude-control systems of various precisions are continuing at the Ames and Langley Research Centers. Work on systems providing control through the use of inertia wheels, gyros, and magnetic coils is going forward. At Ames, various methods of introducing damping (checking vibrations) in control systems were investigated. Results were promising; at present a pointing error of less than 0.5 second of arc can be obtained with a system employing inertia wheels. Other studies are planned to study damping techniques for varying types of attitude control.

Stability and Control of Entry Vehicles

Studies of Lateral Movements of Entry Vehicles -- NASA has investigated many problems that will be encountered by manned vehicles entering the earth's atmosphere -- for example, the extremely critical flight path or trajectory that must be followed to stay in the entry "corridor." Useful, simplified methods for analyzing entry trajectories have been developed. Attention was heretofore devoted primarily to trajectories of entry vehicles not having appreciable lateral movement. Recently, however, work has been extended to take lateral movement into account. For an entry vehicle to make a landing at a specified point on the earth's surface, the ability to maneuver laterally is essential.

A method of calculating the lateral range of entry vehicles capable of generating lift (that is, having lifting bodies or wing-like aerodynamic structures similar in purpose, if not in size, to those of conventional aircraft) and of banking to execute a turn has been developed at Ames. Factors that must be taken into account are the speed and angle of entry, and the amount of lift the wing or airfoil produces in comparison with the amount of drag (called "lift-to-drag" ratio). The lateral movement and landing point can then be calculated for various angles of bank. Calculations indicate that bank angle of 45 degrees will yield the maximum in lateral range for satellite vehicles entering the earth's atmosphere. Higher bank angles would greatly increase the aerodynamic heating and cause the craft to decelerate too rapidly.

Use of Drag Control During Atmosphere Entry -- Studies of the effect of varying the drag of a ballistic (nonlift) entry vehicle have been renewed recently at Ames. Analysis indicates that the corridor for safe entry of such a vehicle to the atmosphere may be considerably enlarged by varying the drag of the vehicle, using drag brakes similar in principle to those employed on conventional aircraft. In a typical example considered, the entry corridor depth was increased from seven miles to 30 miles by varying the drag; this in turn would reduce the degree of accuracy required in guidance. However, the use of drag brakes introduces new aerodynamic heating problems that the entry vehicle must cope with.

Aerodynamic Heating Problems

Heating on Lifting Entry Vehicles -- An investigation was completed at Ames of the aerodynamic heating of a lifting entry vehicle having a conical shape, somewhat flattened on the upper side, with a spherical nose and flap control surfaces. Such a shape gives rise to more complex aerodynamic heating problems than does that of a simple ballistic (non-lifting) vehicle, since the shape is less blunt, has thin control surfaces, and assumes various angles when coming back into the atmosphere.

A model, instrumented to measure heating rates, was tested in the high-energy air stream of the Ames 12-inch shock tunnel. A photograph of the model under test shows the complicated flow of the extremely hot incandescent gaseous plasma surrounding the body and control surfaces. Extremely high rates of heat transfer to the control surfaces were measured. Test times were kept short so that body temperatures would not build up intolerably.



Model of entry vehicle in 12-inch shock tunnel, showing the luminous quality of the high-speed airstream.

Aerodynamic Heating of Returning Spacecraft -- Several other studies at both Langley and Ames on aerodynamic heating are devoted specifically to problems that would be encountered by a manned spacecraft returning to earth from the vicinity of the moon or a planet. The vehicle would enter the atmosphere at a speed much greater than that of a satellite orbiting the earth.

The pilot will be able to withstand only limited amounts of decelerating during entry; slowing too rapidly would impose intolerable "g-forces" on the occupants of the spacecraft. On the other hand, if the vehicle fails to slow down enough, it will not enter in a single pass, and will traverse the harmful radiation zones repeatedly. Thus, the entry path must be restricted to relatively shallow angles.

Under these conditions, the returning vehicle undergoes intense heating as it enters the upper atmosphere. Air passing through the strong shock wave in front of the vehicle is compressed and heated to the extent that "dissociation" takes place -- some molecules break up into component atoms.* A simplified method has been developed that permits estimate of the effects of this complex flow on heat transfer to the vehicle and the flight conditions under which it becomes a problem to be identified.

Theoretical Predictions of Heat Transfer and Pressure -- NASA's research centers are constantly seeking ways of improving the accuracy of theoretical predictions of pressure distributions and skin temperatures at hypersonic speeds, to bring them into closer conformity with the events that take place in actual flight. This is often a lengthy process, involving "cut and try" methods of checking and re-checking theory against instrument-recorded data. Rocket-boosted models, wind-tunnel models, and models in specialized facilities such as ballistic ranges have been used to seek improved means of predicting pressures and temperatures at speeds many times that of sound.

In one case, with a rocket-boosted model that reaches speeds of Mach 9 - 11, it was found that both pressures and heat transfer were about 30 percent lower than had been theoretically predicted on the basis of previous experiments at lower speeds. However, a machine computation method,

* The processes involved are quite complex. The flow also becomes ionized, and while the break up is going on, some atoms are also recombining to form molecules again.

newly developed by the Space Technology Laboratories, predicted pressure distribution which agreed well with the measurements recorded in flight. Also, a new method of predicting heat transfer, based on a recently published theory (called the Vaglio-Laurin theory) showed similarly good agreement.

Thermal Radiation Protection -- During entry into the atmosphere at speeds greater than 25,000 mph (for example, on a return flight from the moon or planets), heat is radiated to the vehicle from the hot "plasma" it encounters. This adds to the already high convective heat transfer that occurs during entry from satellite (orbital) speeds which take place at about 15,000 mph.

It has been known for some time that convective heating can be reduced by injecting a gas through the vehicle walls to form a thin film next to the outside surface. If the gas is a strong absorber of radiation, it may protect the surface of the vehicle not only from convective, but also from radiative heating. At Ames, the conditions under which the process might be desirable were investigated, as well as the absorbing properties that the injected gas must have to be effective.

It was determined that gas injection for thermal protection is most effective when employed with a vehicle whose surface materials will absorb large amounts of radiation. In such a case, the total heating can be reduced by as much as two-thirds by injecting an absorbing rather than a non-absorbing gas. On the other hand, use of an absorbing gas is actually detrimental if used with a vehicle whose surface reflects most or all radiation (since such a vehicle needs no radiation protection); convective heat transfer is increased because radiant energy is absorbed in the gas near the surface of the vehicle.

Between these two extremes is a "break-even" point, at which there is no advantage in injecting an absorbing rather than a non-absorbing gas. The "break-even" point depends in part on other physical conditions and ranges from 30 to 80 percent of the theoretically "perfect" reflector for the examples studied. Among the absorbing gases that appear promising for this application are cesium, potassium, and rubidium.

Chemical Rocket Propulsion

NASA research on chemical rocket propulsion centers around high-energy propellants -- particularly hydrogen-oxygen

and hydrogen-fluorine -- which promise to carry much larger payloads than can be lifted with propellants now employed. Hydrogen-fluorine has the highest energy content of any stable chemical combination. However, they impose difficult operational problems because they have very low boiling temperatures (hydrogen boils at -423°F) and because fluorine is extremely corrosive and toxic.

Several NASA projects are developing design criteria for efficient, lightweight, reliable components for hydrogen-oxygen and hydrogen-fluorine rocket systems. At Lewis Research Center, experiments with hydrogen-oxygen thrust chambers have provided extensive data on wall-cooling, propellant injector performance, and combustion stability over a wide range of operating conditions. Information from these experiments, which are still going on, will be utilized in Saturn upper-stage hydrogen-oxygen rocket engines (See Chapter 8, "Propulsion and Nuclear Energy Applications for Space," pp. 87-90).

In experimental studies of hydrogen-fluorine combinations, thrust chambers with very large expansion nozzles and very low chamber pressures have been used to duplicate as closely as possible the most desirable design characteristics for space propulsion. Results have been excellent, closely approximating theoretical predictions. Other, related work includes studies of propellant injectors for the purpose of designing thrust-chambers which can be throttled. Heat transfer data are being obtained to provide a reliable basis for designing thrust-chamber coolant passages. NASA plans research on components and, ultimately, on complete systems. Equipment is being prepared to study components of hydrogen-fluorine rocket systems -- the flow lines, control valves, tanks, and pressurizing systems.

Sea-Level and High-Altitude Simulators -- At Lewis Research Center a pressure-fed hydrogen-fluorine rocket system (representing powerplant requirements for deep space propulsion) is being readied for operation in a recently completed test facility that simulates sea-level pressures. Another facility, simulating high-altitude and space conditions, is under construction at the Lewis Plum Brook site near Sandusky, Ohio. It will test complete hydrogen-fluorine engine stages.

Combustion Research -- Work is continuing to learn more about rocket combustion and how it takes place. Attention centers on factors that control stable, and unstable (pulsating) burning. The combustion rate of many propellants is governed by the physical process of spray evaporation. Research is being focused on spray properties at the beginning

of combustion, and how they change. During the report period, experiments with burning spray in a rocket combustor yielded data on characteristics during all phases of burning. This constitutes a major step toward design of rocket combustors that will have predetermined performance for engines of various sizes.

Pulsating or unstable combustion continues to be a severe problem. Theoretical studies of the way pressure oscillations build up have produced qualitative criteria for engine stability. Continuing research on critical conditions that affect liquid spray and cause it to break up, and the rates at which the break-up takes place, has also led to a criterion for engine stability. Results of these studies are being applied in NASA's engine development program.

Hypergolic and "Storable" Propellants -- Hypergolic propellants are types that ignite spontaneously when the ingredients are brought in contact. These include "storable" propellants which can be kept in vehicle tanks without evaporating, instantly ready for firing. Results from research on reaction processes of such materials indicate that maximum heat output -- and hence, maximum power -- can be obtained only when mixing takes place at a certain critical rate. The work is being extended to systems having a higher total energy content, to learn if this behavior is general.

Fuel Sloshing in Rocket Tanks -- Sloshing fluids in the tanks of large liquid-propellant rockets can cause oscillations that disturb guidance and control systems. Severe sloshing may even damage the rocket structure. To reduce or eliminate oscillation, full-scale and reduced-scale model tanks are being tested on the ground. This method is not entirely satisfactory because the natural oscillation frequency of the fluid tank on the ground is fixed, but when a rocket is in flight, the frequency increases with acceleration.

Ames Research Center has conducted research to determine the effectiveness of a variety of fuel-tank baffles at various frequencies, amplitudes, and fluid depths. Early tests employed simple equipment. Later, complete models of tank-baffle designs were used. The tests have led to better understanding of the problem, and should permit the design of baffle systems of minimum weight. In a related study, performance of the guidance and control system of a large rocket vehicle with fuel sloshing in the tanks is being determined. Mass and movement of the fuel in the tank and

baffle combination are represented by a "mathematical model" -- formulae or equations that can be fed into a computing machine. Two "models" are being used. In one, the sloshing fuel is treated as a pendulum. In the other, a weight oscillating on a spring represents the sloshing fuel. Small-scale experiments are checking the accuracy of both models. Incomplete results indicate that both are useable representations of fuel oscillation.

Nuclear Propulsion*

NASA is developing two types of nuclear propulsion systems (described in Chapter 11 of NASA's Third Semiannual Report to Congress): 1) nuclear heat transfer rockets and 2) nuclear electric generation systems. Although numerous technical problems remain to be solved, none appear insurmountable. Examples of the basic research that supports NASA nuclear propulsion programs follows.

Heat Transfer Research -- The higher the temperature at which the reactor of a nuclear heat-transfer rocket can operate safely, the better the over-all system will perform. At Lewis Research Center, work is going forward on experiments to learn more about the heat transfer and pressure drop characteristics of the propellant that flows through the reactor. Electrically heated tubes are used to simulate the heat of the reactor, and hydrogen gas is pumped through the tubes. Results indicate that maximum surface temperatures were about 5,400°F. The rates of heat transfer and pressure drop and their relationships to each other showed good correlation with the results expected. Such experiments are necessary to improve the design of propulsion reactors that will eventually be employed in nuclear rockets for space exploration.

Gaseous Reactor -- Feasibility of a more advance type of reactor for nuclear propulsion systems is also being investigated at Lewis. Called a gaseous reactor, the device would utilize gaseous uranium in a round cavity as the reactor fuel; hydrogen (the propellant) would be passed through the cavity and be heated by direct collision with the fission fragments. The temperature of the propellant is expected to be extremely high. As explained earlier, the greater the temperature within the reactor, the greater the efficiency of the propulsion system. In the heat transfer reactor,

* See also pp. 105-109.

about 800 pounds of thrust may be produced for each pound of hydrogen flowing per second (specific impulse of 800). In a gaseous reactor, this may be increased more than three fold, to about 2,500.

A major problem is to keep the uranium gas separated from the propellant. One approach employs a propellant flow pattern that takes the form of a vortex. The uranium gas, outside the whirling currents of the vortex, would tend to stay in the cavity, and only small quantities would be ejected with the propellant.

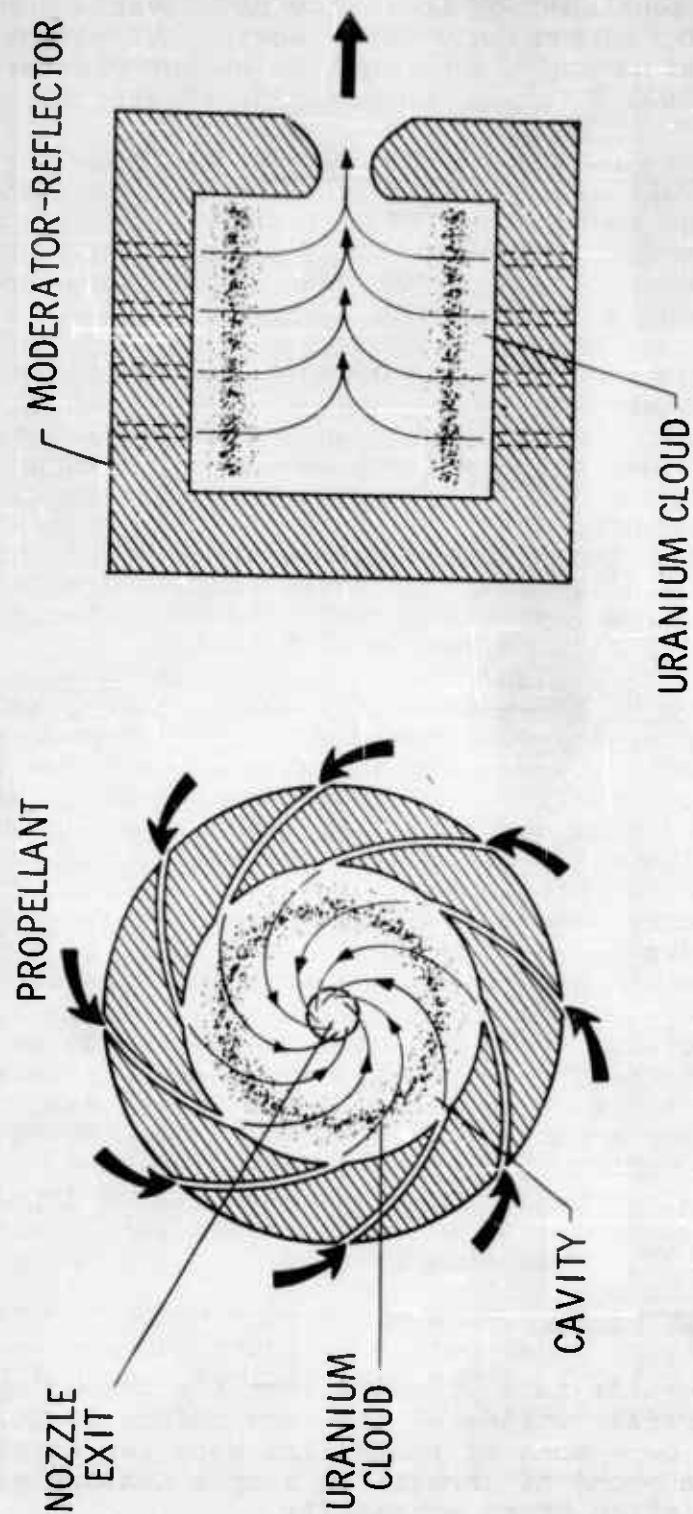
To check the analysis of vortex flow, mixtures of air and bromine were passed through a lucite test chamber. Through glass windows in the lucite, optical measurements of the bromine concentrations were made; instruments (static pressure taps and total pressure probes) were used to measure velocity and pressure. Preliminary data, indicated a measurable degree of separation between the air and the bromine. However, while encouraging, these results are far removed from a practical system. Proof that the gaseous reactor is feasible will require much more research.

Neutron Probe -- An experimental device, known as a neutron probe, has been designed and built at the Lewis Research Center, as an aid in determining the action of neutrons in a reactor. Neutrons are subatomic particles, with no electrical charge, that are used to "bombard" and split uranium atoms to produce controlled nuclear power. Information on this behavior is essential when starting up a new reactor, before the reactor can be used for research. Previous reactor instrumentation has involved a measuring process that is both time consuming and expensive.

The neutron probe has been tested in the NASA Zero Power Reactor* at Plum Brook. Experimental results are shown in the figure on p. 140. The counts per second** indicated are a measure of the number of neutrons in the particular region of the instrument. Because of the detector

* A research reactor, now under construction, used for experimental purposes only. Designed to operate at a very low output level -- the bare minimum required to sustain a nuclear chain reaction.

** Each neutron detected by the probe is recorded as one impulse, or count.



Cutaway view of gaseous reactor. Propellant is injected with a whirling motion into the round cavity, through openings in the sides. As the propellant passes through the uranium cloud it is heated to high temperature and expelled in a whirling jet vortex, indicated by arrows. The uranium cloud remains separate from the propellant, and is not drawn into the vortex.

shows excellent ability to follow rapid variations in power, it may be useful not only for checking out research reactors, but may also be applied to nuclear rocket reactors and to stationary reactors used to generate electrical power.

New Nuclear Systems Division at Lewis -- During the report period, a Nuclear Systems Division was established at Lewis Research Center. The new division will conduct complete systems research and analyses of nuclear propulsion and power systems; mission and application studies of these systems; and propellant handling research programs in a zero-gravity environment. The division will provide technical support and direction to a Nuclear Engines Project Office that has also been established at Lewis as a field unit of the Office of Launch Vehicle Programs of NASA. These changes emphasize the importance that NASA attaches to the use of nuclear energy for space propulsion and power generation.

Electric Propulsion*

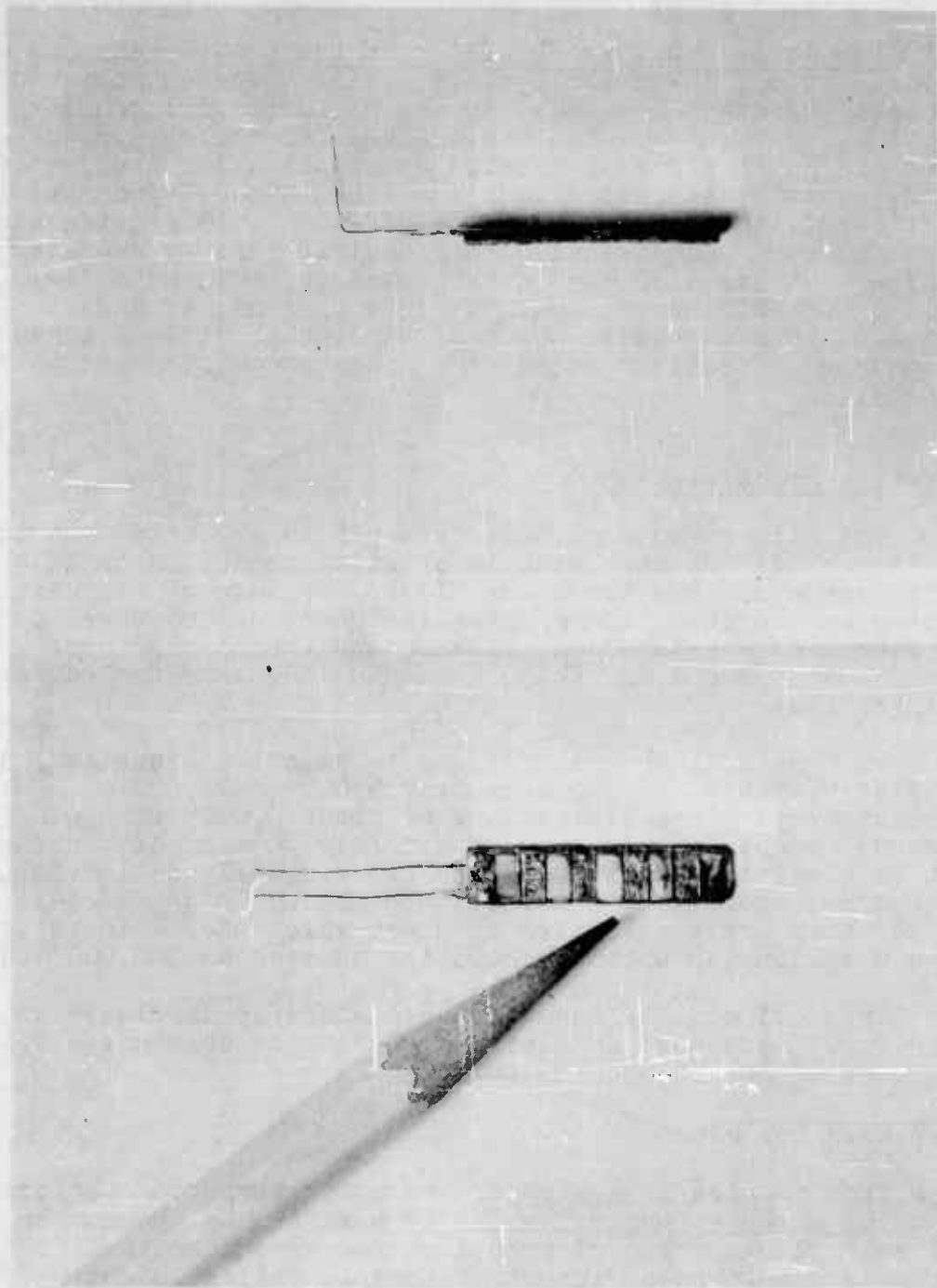
The main purpose of NASA research on electric propulsion is to provide industry with information needed to build high-performance systems for space flight missions of the next decade and beyond. The program includes work on three types of electric rockets: ion, plasma, and thermo-electric. (See NASA's Second and Third Semiannual Reports to Congress, Chapter 11.)

Conventional thermal rockets (chemically propelled) can attain velocities of approximately 9,000 to 25,000 mph (with present temperature limitations of about 5,000° to 6,000°F).. Electric propulsion systems do not rely on high temperatures, but on electrical voltage, which has virtually no limits. If charged propellant molecules are placed in an electric field, they are accelerated to great velocities. In theory, such a system can attain velocities as high as 300,000 mph.

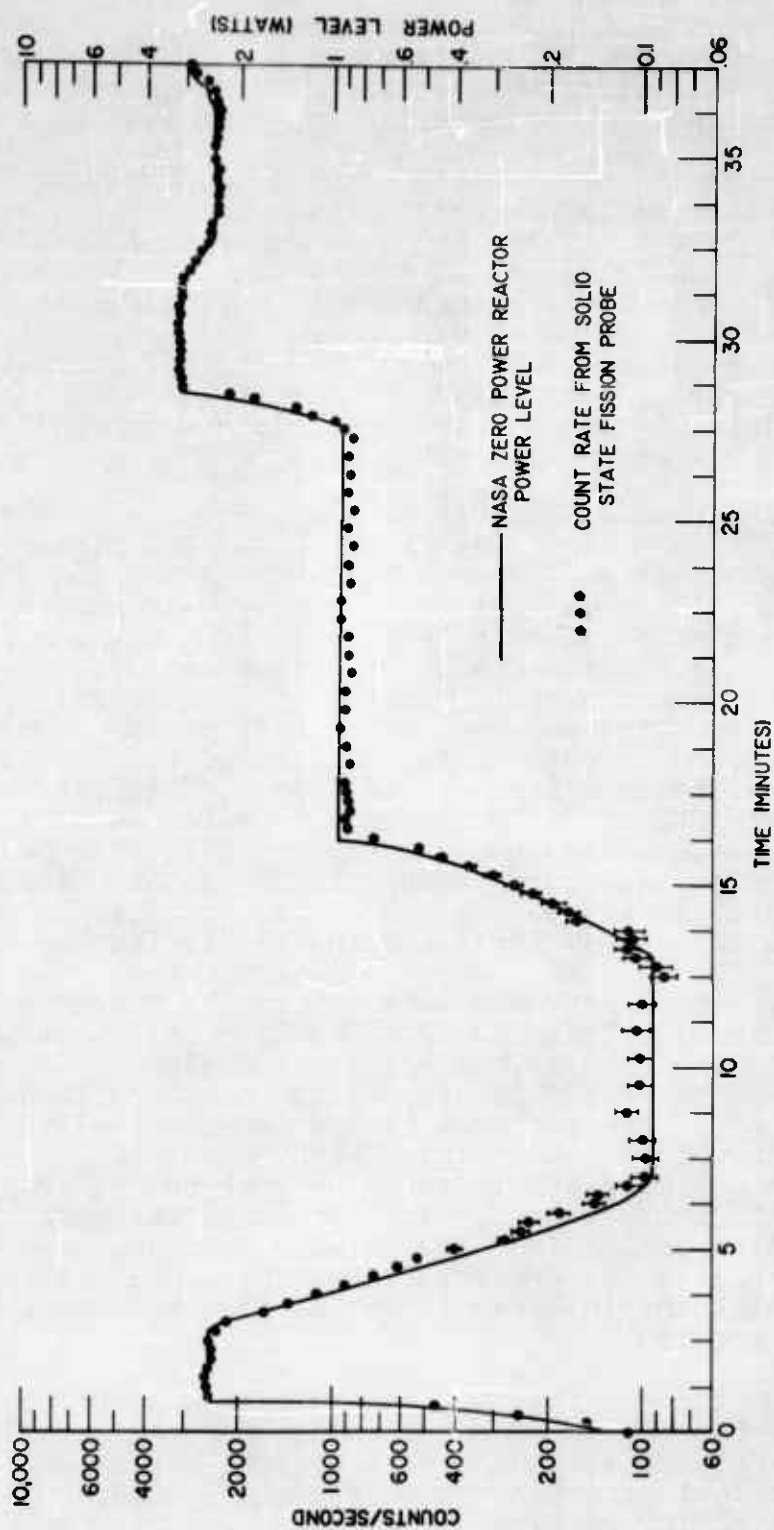
Chemical rockets can achieve a specific impulse** as high as 425 seconds; an electric rocket can obtain specific impulses of 10,000 seconds or more.

* See also pp. 102-104.

** Specific impulse is a standard term for measuring performance of a rocket engine -- the term refers to the number of seconds one pound of propellant mass can continue to produce one pound of thrust. A simple analogy might be the miles per gallon of an automobile.



Neutron probe, front and side views. This small device sends an electrical signal to a counter each time a neutron strikes it.



Power response curve for solid state neutron probe.

For space flight within the solar system, specific impulses of about 1,000 seconds are desired. This should be adequate for such missions as raising earth satellites from low to high-altitude orbits. For deep space and other advanced missions, higher specific impulses will be required.

Experiments and investigations in progress at Lewis center on very small electric rocket engines that can be tested in glass bell jars and with other bench-scale apparatus. Four stainless steel vacuum tanks (diameters of 3½ and 5 feet) in which pressures below one billionth of atmospheric pressure can be obtained, are used to investigate larger ion rockets. Tanks with diameters of 15 feet and 25 feet are being fabricated. In these, it will be possible to investigate larger electric rockets and to evaluate interactions of smaller rockets in clusters.

Ion Rockets -- Ion rockets are particularly suited to operation at very high specific impulse; the higher the impulse, the higher the power efficiency of the ion rocket. A year ago, NASA scientists had achieved ion rocket power efficiencies of 58 percent, with specific impulses of about 20,000 seconds. Since then, ion rocket efficiency has been improved for lower specific impulse. One type of ion rocket that has been developed and tested uses cesium propellant which is passed through an ion emitter of porous tungsten. This engine achieved a power efficiency of slightly more than 50 percent, at 12,000 seconds specific impulse. However, the porous tungsten emitters are difficult to fabricate and to join to surrounding engine parts. Satisfactory methods have yet to be devised. Research on these problems is continuing both at Lewis and in private industry.

An alternate approach -- known as the "reverse feed" system -- is also under study. Solid, rather than porous, tungsten is employed as the emitter. Cesium is fed onto the ionizing surface from propellant injectors located "downstream" of the emitter. The arrangement eliminates fabrication problems associated with porous tungsten, but introduces new difficulties: as neutral cesium propellant atoms are injected onto the emitter, some encounter high-velocity ions coming from the emitter, and charge-exchange takes place. In the process, low-energy ions are formed, some of which are intercepted on the accelerating electrode and cause erosion.

Recent theoretical studies indicate that proper design can reduce the charge-exchange enough for the reverse-feed engine to compare with engines employing porous emitters. The theoretical potential of this engine, however, has not been achieved in practice.

These and other serious problems with cesium propellant have dictated development of mercury as an ion source. Ions are generated by bombarding mercury vapor with magnetically constrained electrons. Power efficiencies well above 60 percent have been measured at a specific impulse as low as 5,500 seconds. Propellant utilization of about 80 percent has been demonstrated.

How to neutralize the ion beam as it leaves the rocket nozzle is an unsolved problem for all types of ion engines. In theory, introducing electrons which carry negative charges into the beam of positively charged ions should neutralize it. Recent experiments to test the theory indicate that this technique reduces beam spreading to a marked degree, indicating that the ion beam has been at least partially neutralized. Further experiments are required to learn whether this method can completely neutralize the ion beam. Apparatus and instrumentation have been fabricated, and experiments will soon be under way. Tests in vacuum tanks may leave doubt about neutralizing the ion beam in space. Ultimately, a flight experiment may be required.

Plasma Rockets -- Work on a number of plasma acceleration methods (described in Chapter 11 of NASA's Third Semi-annual Report to Congress) has been narrowed to two devices showing good potential over-all power and propellant utilization efficiencies. One is a traveling-wave plasma accelerator which employs a radio-frequency power supply. A 40-kw power supply has been purchased and initial experiments are in progress. The other method employs two coaxially-mounted (one inside the other) tubes between which an arc forms, each arc producing a "pulse" acceleration in the plasma. Apparatus for studying this acceleration scheme was being designed as the report period closed.

A number of techniques for generating plasma efficiently are being investigated at Lewis Research Center. Plasma sources under study include radio-frequency induction heating of a gaseous propellant, three different configurations of electric arcs, and an oscillating-electron device. Any of these generators could be combined with any of the accelerators into a plasma rocket system.

Electric Thermal Rockets -- For missions requiring a specific impulse of 1,200 seconds or lower, such as satellite orientation and orbit adjustment, electric-thermal

rockets are of interest. A 3-kw electric arc rocket* was successfully operated at 0.05 pounds thrust and 500 seconds specific impulse. Further tests will be made at higher thrust levels and with a specific impulse up to the design requirement of 1,000 seconds. A much larger engine (30-kw) is being fabricated*. Utilizing an electrical resistance-heated heat exchanger, the engine is designed to produce one pound of thrust and 1,000 seconds of specific impulse.

The research programs for these two engines include evaluation of various propellants and development of low-erosion electrodes for the electric rocket.

Materials for Space Structures

Demands for new and improved materials and for methods to fabricate them are increasing as a result of the many structures being developed for high-performance aircraft, entry vehicles, and spacecraft. To satisfy these demands, NASA is continuing broad and varied research efforts.

High Temperature Materials -- One of the most severe requirements of materials for space structures is satisfactory performance at high temperatures. Present nickel- and cobalt-base superalloys are useful only up to about 1,800°- 2,100°F. For higher temperatures, attention must be turned to refractory materials, such as niobium, tantalum, and tungsten. For some time, Langley has been investigating fabrication and coating problems associated with molybdenum alloy sheet. More recently, studies have begun of fabrication problems of tungsten sheet and tantalum-tungsten alloy sheet. Preliminary results indicate that currently available commercial tungsten sheet is too brittle and subject to layer separation (delamination) for fabrication into the intricate shapes required. Continued research will be required to eliminate these deficiencies. Tantalum-tungsten alloy sheet, on the other hand, apparently presents no forming problems. However, experience is limited, since only small quantities of this alloy are available for study.

Studies of High-Temperature Coating Materials -- Materials such as stainless steel or the nickel- and cobalt-based superalloys develop protective oxides that inhibit

* Details of work on the 3-kw and 30-kw engines are in Chapter 8, Propulsion and Nuclear Energy Applications for Space, pp.103.

oxidation at high temperatures. The oxides of the refractory metals at their proposed use temperatures, however, are unstable and volatilize (turn to gases). When this occurs, new metal is continually exposed to further oxidation. One possible way of handling this problem is to apply a coating to the metal.

Studies have been made at Langley to learn what coatings are most suitable for protecting tungsten sheet and tantalum-tungsten alloy sheet in the 2,000°F to 3,000°F temperature range. Commercially available coatings and coatings being developed at NASA have been tested, but so far none of outstanding performance have been found. Study is continuing.

Theoretical studies are also under way to determine why surface oxides are instable and volatile. Special attention is directed to molybdenum trioxide. There are some grounds for hoping that suitable alloying will prevent the metal from oxidizing rapidly at elevated temperatures.

Studies of Surface Emissivities of Materials -- The temperatures encountered by the structures of aircraft that operate in the atmosphere, and of entry vehicles that enter the atmosphere at high speeds, in large part depend upon emissivity* of the surface of the structural material. In view of the importance of emissivity on vehicle temperature, continuing studies in this area are being made at Langley. A special black-body furnace** has been developed for determining emissivities for materials, for example, ceramics, that cannot be heated by electrical resistance methods. To date, the total normal emissivity of boron nitride, a high-temperature material that displays good oxidation resistance and is semitransparent to heat radiation, has been measured over the range from 1,000°F to 2,000°F in this furnace. Techniques are also being studied to allow measurements of emissivity of coated refractory metals.

* The temperature is controlled by the ability of the material to cool itself by radiating the heat that is put into it. This ability to radiate is (roughly) the emissivity.

** An electrically-heated box, painted black on all inner surfaces, in which this test material is heated. Special instruments measure the emissivity of the test material, and the furnace, being entirely black, adds nothing to the total.

Fatigue Characteristics of Metals -- An important method of judging the resistance of structural materials to fatigue is the rate at which cracks occur and propagate. Practically all information on this subject deals with cracking under repeated, steady pressures or stresses. Recent tests at Langley of aluminum-alloy sheet specimens have shown that an appreciable delay in crack propagation is encountered, and is followed by a resumption at a lower rate when the stress amplitude is reduced. Photographs of surface of fractures are also being studied in the hope of deducing the kinds of loads or stresses that caused the fractures. Results of these studies should contribute to understanding of fatigue and to better methods for assessing it in the design stages. The work is being continued on high-strength steels of the types used in launch vehicle tanks and in the structures of advanced vehicles.

Materials for Powerplants

The search for better materials for space propulsion systems and a better understanding of why materials behave as they do under the unique conditions encountered in space and in high performance powerplants continues at the Langley, Ames, and Lewis Research Centers. These basic investigations promise better understanding of how and why materials fail. Studies have included the effects of heat treatment on the mechanical behavior of ceramic materials, and measurement of the way materials bend or deform for single crystals subjected to both chemical treatment and thermal treatment; these treatments affect their purity, surface structure, and internal structure in known ways.

Experimental Study of the Growth of Voids in Silver -- Voids or cracks that form in metals when they are deformed constitute one of the principal processes leading to breakdown or failure. The growth rate of these voids has been measured in silver at several temperatures. It was shown that minute defects produced during deformation migrate to grain boundaries where they collect to form voids. The rate of void growth increases with increasing temperature. When several small voids are close together, they attract each other and have a tendency to join; this occurrence appears to be of major importance in the formation of voids. Further studies are being conducted to confirm the interpretations of these experiments.

Materials for Cryogenic Propellant Tanks -- This project was undertaken to permit rocket fuel tanks to be made lighter without losing strength. Sheets of titanium alloys were subjected to conventional strength tests; some

were stronger (in ratio of density to strength) and tougher at room temperatures than any of the best heat-treated steels now available. They also stood up well at very low (cryogenic) temperatures.

Several alloys each of aluminum, austenitic stainless steel,* and titanium have been tested at cryogenic temperatures. It is possible to state tentatively which are the better alloys of each metal but not which metal is most promising for minimum weight application. This is because the strongest alloys are also the hardest to work and are most affected by welds, holes, and pipe fittings. Equipment has been designed and tests have started on small-scale propellant tanks to determine their strength at temperatures down to -423°F .

Tungsten and Tungsten Alloys in Tension at Very High Temperatures -- Lewis Research Center is working to develop tungsten and tungsten alloys that can be fabricated or shaped. Melting and casting of tungsten results in coarse grain structure that is difficult to work. Hot extrusion of tungsten alloys does not fully refine the grain structure. Addition of small amounts of molybdenum improves the internal structure of the tungsten, and should make it easier to work and fabricate. NASA scientists are continuing to assess the mechanical properties of these and other tungsten alloys at temperatures as high as $4,500^{\circ}\text{F}$.

Boiling Sodium Corrosion Research with Refractory Metals -- Auxiliary nuclear and solar power systems for space vehicles will use liquid metals as a working fluid to drive the electrical generator in much the same way as steam is used in conventional power plants. The efficiencies of these systems will be much improved if they can operate at temperatures of about $2,000^{\circ}\text{F}$. Materials such as steel have little strength at these temperatures. Consequently, high strength-high temperature refractory metals -- niobium, tantalum, molybdenum, and tungsten -- must be used. A project to determine the corrosive effect of the "working fluid" (sodium, potassium, or rubidium in the form of liquid and vapor metal) on these metals at temperatures of $2,000^{\circ}\text{F}$ and higher is now under way at Lewis Research Center. Experimental apparatus has been fabricated. In this project, doughnut-shaped metal loops, partially filled with liquid sodium or potassium, are

* A type of heat-treated carbon steel characterized by high strength, ductility, and toughness.

heated so that the liquid metal in the bottom section boils. The metal vapor rises to the top of the loop where it cools, condenses to a liquid, and flows back down the walls of the loop to the bottom where it is brought to a boil again. Thus, on a small scale, the effects of corrosion of liquid metal fluids on refractory metals can be evaluated over long periods of time and under varying temperatures.

Alloy Systems for High Temperature (1,800°-2,100°F.)
Use -- Temperature, atmosphere, and imposed stresses all affect the behavior of materials. Alloys that, under high stresses, can withstand corrosive atmospheres in the 1,800° to 2,100°F temperature range have much potential in many space applications. Exploratory studies of nickel- and cobalt-base alloys at Lewis have been narrowed to a single nickel-base alloy series. Several of these alloys have been developed. Each has demonstrated substantial improvement in physical properties over its predecessors. The alloys were evaluated by means of conventional tension tests (stress-rupture and creep tests). The latest alloy has strength properties well over those of commercially available nickel-base alloys. It can support a load of 15,000 pounds per square inch (psi) for 200 hours at a temperature of 1,900°F. It appears that this alloy will also be ductile and easy to shape.

Effects of Micrometeoroid Impacts on Space Structures --
Also under study are some of the effects of meteoroid impact on the strength of materials. These will be investigated by: 1) a satellite experiment on a Scout rocket (scheduled for launching in early 1961) in which penetrations on two thicknesses of stainless steel will be counted, and 2) impact studies (which approximately simulate micrometeoroids) on stressed sheet material to determine how much stress space structures can stand, with or without penetrations.

Three micrometeoroid impact detectors are being prepared for the Scout experiment. The first has been sent to Langley for environmental testing. Fabrication of the other packages is on schedule.

Nozzle Materials for Solid Propellant Rockets -- During the report period, studies of material for solid-propellant rockets continued at Lewis. The test installation, consisting of a small-scale rocket motor that simulates the exhaust gas composition and temperatures encountered in full-scale solid-propellant rocket engines, was thoroughly checked out. Tests on tungsten, high density graphite, molybdenum, and certain ablating materials were initiated with non-aluminized

(4,800°F) and aluminized (5,600°F) propellants.* Of these materials, tungsten resisted erosion best. The program will be expanded to study nozzle materials, using recently developed propellants which can achieve temperatures as high as 6,300°F.

Structures of Manned Space Cabins

Coming generations of spacecraft must operate with ever greater safety and reliability in the extreme conditions of space. Particularly is this vital for manned space flight. Manned spacecraft must be able to withstand the stresses and pressures of launching. Once in space, they must resist the impacts of micrometeoroids and the effects of vacuum and radiation. Finally, they must stand up under the great heating and acceleration of entry into the atmosphere.

One of the most important portions of a manned spacecraft will be the cabin. NASA is investigating two cabin designs: 1) a structure folded during launch and erected in space (with an inner "package" to protect the astronaut until the main structure opens up; and 2) a rigid structure.

Erectable Structures -- Various aspects of the first named are being studied at Langley Research Center. Preliminary packaging and inflation tests have employed erectable models (30 inches in diameter) of toroid** space stations to study folding patterns and packaging requirements. The results indicated that a torus to provide living quarters of a given volume in space could be easily packaged in approximately 8 percent of that volume. This work will be continued on 10-foot and 30-foot diameter toroid models.

Flexible, strong, light structural material that can protect man against space conditions must be developed. To this end, two small NASA study contracts were recently completed by the Goodyear Aircraft Corp., Akron, Ohio. These contracts called for preliminary evaluation of inflatable

* Adding aluminum to the propellant raises the burning temperatures; aluminum burns with an extremely intense heat.

** In the form of a torus, or anchor ring, a doughnut-shaped structure with a hole in the middle.

suitable fabric materials; detailed studies of elastomers,* with emphasis on effects of temperature, vacuum, and ultraviolet radiation; studies to determine the best methods of folding materials; and structural design and analysis to determine favorable torus configurations or shapes and accomplish preliminary design of attachments, seams, and feed-throughs for lines, cables, etc.

Based on these studies, 3-ply fabrics have been developed that are composed of neoprene or butyl rubber elastomers and nylon or dacron cord reinforcements. The fabrics meet stress, folding, and weight requirements, and could survive in space for at least 30 days. NASA's research centers are testing elastomers, reinforcing cords, and protective coatings over longer periods -- six months or more.

Rigid Space Cabins -- Rigid space cabins must withstand strong external pressures during launching as well as internal stresses peculiar to space. At Langley, the strength of thin shells subjected to combined internal pressure and external compression and bending is being investigated. In addition, NASA has awarded research grants to educational institutions.

At the Langley Research Center, numerous large, thin-walled cylinders -- with and without ring stiffeners -- have been tested until they failed. Measured strengths agreed with theoretical predictions for high internal pressures, but were much lower than predicted for lower internal pressures. This defect has long been recognized; it is usually attributed to imperfections in manufacture. Recent theoretical investigations have shown, however, that this is only part of the trouble. There is also inherent, and apparently unavoidable, weakness in thin-shelled cylindrical structures. Work is continuing toward more reliable designs.

Studies of Pressure Vessels -- The manned space cabin or compartment is essentially a pressure vessel, much like a boiler or tank. Many other types of pressure vessels will be required for space missions. One method of building pressure vessels is to wind ultra-high-strength filaments on a form and then coat them with plastic as a unifying matrix. If some of the filaments should be suddenly broken by damage, such as meteoroid impact or accidental piercing, a safe design would allow the adjacent filaments to carry

* Elastic, synthetic substances, such as plastics, having some of the characteristics of natural rubber.

the load without breaking. Studies at Langley have shown that the more filaments are broken, the higher the stress is concentrated in the adjacent filaments. However, the ratio between the dynamic and static stress concentration is virtually independent of the number of broken filaments, the maximum dynamic stress being about 20 percent higher than the static stress.

Landing Impact Structures -- The conventional way to absorb impact energy on landing is to use hydraulic shock-absorber struts. For spacecraft, the impact will often be quite severe, and the deleterious effects of the space and entry environment on lubricants and shock-absorber fluids may make conventional shock absorbers impractical. "One-Shot" landing gears with replaceable yielding metal elements, for example, is a promising approach that is being investigated at Langley. Another involves the use of skids of various kinds. In one phase of this investigation the properties of suitable yielding elements and skids are being studied experimentally and theoretically. In another phase, models of typical winged spacecraft, such as Dyna-Soar (see Chapter 12, Special Research Projects, pp. 160-164), are tested with appropriate landing gear to determine impact accelerations and dynamic behavior.

The studies indicate that satisfactory characteristics can be obtained from simplified landing gears. Special difficulties arise when one of the main skids touches down before the other, but proper location of the skids will reduce the demands on piloting techniques that this produces. The yielding elements can be designed to absorb energy by stretching, bending, or crushing.

Fluctuating Loads on Multi-Stage Rockets -- After a large rocket-powered vehicle is launched, it accelerates gradually and passes through the transonic speed range while it is still within the earth's atmosphere. In this speed range (popularly, though not entirely accurately, known as the "sound barrier"), fluctuating pressures act on the surface of the vehicle as shock waves build up. These unsteady pressures, in combination with the steady pressures to which the vehicle is subjected during atmospheric flight, sometimes become so severe that they may cause portions of the structure to fail.

Fluctuating pressures are being investigated in the 14-foot transonic wind tunnel at Ames Research Center. Additional tests and analyses -- taking into account the effects of various vehicle shapes -- are in progress. A

method of estimating fluctuating pressures on the basis of the more easily measured steady pressures is also being sought.

Inflated Sphere Landing Vehicle -- Various means are being studied for landing instrument packages safely on the moon or planets. One simple and promising device is the inflated sphere landing vehicle. The instrument package to be landed will be suspended in the center of a sphere by cords extending from all sides and attached to the sphere's skin. No guidance, control, or attitude stabilization would be required, and payloads that can tolerate several thousand g's acceleration (a very reasonable requirement for certain types of electronic instruments) can be cushioned to withstand impact velocities up to 1,000 feet per second (fps).

Studies of this type of landing vehicle are in progress at Ames Research Center. It has been found that the cords supporting the payload package in the center of the sphere need weigh only half as much as the payload they support in order to withstand impact velocities up to 500 fps. The required sphere diameter will be only 12 feet if the acceleration is 2,000 earth g's. Landing performance has been calculated for various payload weights and landing speeds.

In a related study, the effects of tapering the payload suspension cords are being analyzed. In some cases, a significant increase in the size of the payload can be handled when the cords are properly tapered. Finally, skin stresses of the sphere were analyzed during impact, to establish design requirements based on the strengths of the materials used.

Direct Conversion Electrical Power Systems

As spacecraft grow more and more complex, so do mission requirements. For projected landings on celestial bodies, probing deep space, and orbiting man around the earth, the needs for electrical power increase enormously. Heretofore the approach has been to develop highly specialized electrical power systems to meet specific requirements of a particular space mission. Steps are now being taken to organize research so that it will yield information that can be used in a number of systems. Fortunately, the various means of generating electrical power for space missions have much in common.

No Rotating Parts Required -- Direct conversion systems utilize solar, nuclear, or chemical energy to excite the

positive and negative electrical charges that exist in all matter. A barrier is then imposed between the energetic charges to separate them and provide useable electricity. The term "direct conversion" is used because electricity is generated directly without the need for first producing heat energy to boil a working fluid as is the case in a conventional generating system.

Some of the direct energy converters being studied at the Lewis Research Center are thermionic diodes, plasma diodes, plasma thermocouples, semiconductor thermocouples, and photovoltaic solar cells. All are similar in principle but differ in the nature of the barrier that separates the charge.

With the exception of photovoltaic solar cells, all the above direct energy converters are "heat engines," having similar thermodynamic cycles and operating conditions. For practical applications, each must be able to develop high temperature in order to generate needed power in proportion to weight.

Analysis of Direct Conversion and Conventional Systems -- In connection with this problem, a systems analysis was recently completed at Lewis. A turboelectric power generation system and a thermionic system were compared in some detail. Results indicated that the efficiencies, radiator requirements and the ratio of power to weight were quite similar.

Thermionic and Plasma Diodes -- Studies of thermionic and plasma diodes are again concentrated in the high temperature region; the problem is to handle the electrical power efficiently, and to reduce losses from radiation. The proportion of electrical power can be increased by increasing the current flow and radiation losses can be reduced by shielding. Experimental work is progressing in both areas. Plasma effects are being studied to increase power density, and radiation shields of various kinds are being tried out with plasmas.

The plasmas under study are gaseous forms of the alkaline metals (for example, cesium). The work is closely related to that being carried on in ion jets and nuclear turboelectric research (see Chapter 8, Propulsion and Nuclear Energy Applications for Space, pp. 103-108)

Photoelectric Cells -- Unlike "thermal" energy converters, which depend upon high temperature for improved efficiency, photovoltaic cell converters can be improved

primarily through improved fabrication techniques. The conversion efficiency of the sun's rays by photovoltaic action of silicon is very close to the expected theoretical value. To achieve gains in power to weight, it will be necessary to produce thin, flexible crystalline films of silicon, rather than the bulky "sliced" cells in use today. Experimental films of silicon have been produced and are undergoing preliminary testing.

Special Research Projects

RESEARCH PROJECTS CONVERT THEORY TO REALITY

Flight research projects such as the rocket-powered X-15 experimental airplane and the Dyna-Soar manned orbital glider -- in which NASA and the Department of Defense are cooperating -- take theory learned in the laboratory and, by incorporating it into flying aircraft, convert abstract data into reality. Experimental, ultra-high, ultra-swift aircraft such as these and their predecessors are important for two reasons: they test validity of theory and furnish practical and realistic means of finding out if theoretical studies have overlooked important factors.

The X-15 is the latest of a long series of research airplanes, the first of which -- the X-1 -- brought about the long-awaited breakthrough to supersonic flight. The X-15 will be the first to penetrate to the fringes of space. After the X-15 will come the Dyna-Soar, which will be carried into space by a launch vehicle and return to earth after undergoing the terrific aerodynamic heating that results when a body enters the earth's atmosphere.

The X-15 is a joint Air Force - Navy - NASA program; the Dyna-Soar is a joint Air Force - NASA program. This chapter details over-all progress and NASA participation in both projects during the report period.

THE X-15 RESEARCH AIRPLANE

Two Records Set

Four-Year Speed Record Broken -- On August 4, at the Flight Research Center, Edwards AFB, Calif., the rocket-powered X-15 research airplane No. 1 established a new world's speed record of 2,196 mph -- more than three times the speed of sound (Mach 3.31). NASA test pilot Joseph A. Walker was at the controls. The flight started at 8:58 a.m. PDT, after the airplane had been released from its mother ship at an altitude of 45,000 feet. Walker opened the two rocket engines to full thrust. In four minutes of powered flight before the fuel burned out at 66,000 feet, the X-15

attained the record speed, as Walker said, "for just the snap of a finger." The previous world record (2,094 mph) was set on September 27, 1956, by Air Force Capt. Milburn G. Apt, who was killed when his X-2 aircraft (a forerunner* of the X-15) went out of control and crashed.

The X-15's record flight had been preceded by a number of familiarization flights to acquaint the test pilots -- NASA's Walker and USAF Maj. Robert M. White -- with the handling characteristics of the airplane.

Altitude Flight Record Broken -- On August 12, X-15 No. 1, piloted by Air Force Maj. Robert M. White, broke another four-year record by flying to an altitude of 136,500 feet, surpassing the previous world record of 126,200 feet achieved in 1956 by the late Air Force Capt. Ivan C. Kincheloe in an X-2 research airplane. White reported "a direct contrast in the sky, with a band of light below about 50,000 feet, and higher than that, a very deep blue. There was no restriction on visibility, however -- just a much deeper blue sky." The X-15 climbed at Mach 1.9 and at an angle of 50 degrees. Fuel in the two engines was exhausted at an altitude of approximately 120,000 feet but momentum carried the airplane to the record height of 136,500 feet. Then the X-15 nosed down and glided to 60,000 feet at about 1,000 feet per second, during which time its stability was tested and found to be good. The aircraft glided to a landing on Rogers Dry Lake, at Edwards AFB. The entire flight lasted 11 minutes.

Executes Space Functions

Heat Barrier and Handling Tests -- On August 19, Walker flew the X-15 on a mission to learn more about heating effects and handling characteristics. The airplane was taken to an altitude of about 75,000 feet and brought down in a dive at about the angle (approximately 20 degrees) at which it is expected to enter the atmosphere on one of its design missions. To simulate turbulence that might be encountered, the controls were manipulated to make the X-15 pitch and yaw -- that is, to swing its nose up and down and from side to side.

Estimated 500 Degrees Air Friction Heating -- Heat was estimated to be about 500°F at the major hot spots of the X-15, the nose, leading edges of the wings, and tail surfaces. The aircraft is designed to withstand temperatures as high as 1200°F.

* There have been several high-speed X-airplanes and several versions of the X-1, X-2, X-3, and X-5.

In making these measurements, structural-temperature and aerodynamic-heat-transfer data are obtained from thermocouple and surface-pressure measuring devices. In addition, special paints that indicate temperature are used for qualitative information in support of the measured data. The paints have been valuable in indicating particular areas subjected to greater heat than the rest of the airplane. As expected, no critical or flight-limiting temperatures were experienced.

Other Pilots Test X-15 -- Test pilots Walker and White took the X-15 through additional tests early in September. At the same time, four new X-15 test pilots also began flights. The first was made during the week of September 13 by Navy Lt. Cmdr. Forrest S. Petersen. The other three new pilots are Air Force Capt. Robert R. Rushworth, and NASA pilots Neil A. Armstrong and John B. McKay. Each will make two flights to familiarize himself with X-15 No.1.

XLR-99 Engine Being Installed in X-15 No.2

Tests With New Engine -- X-15 No. 2 was being fitted with the final, much more powerful (57,000-pound-thrust) XLR-99 engine. Test flights with the new unit by pilots White and Walker were delayed when the engine was removed to replace a corroded hydrogen peroxide tank. Initial powered flights will use only about half the engine's rated potential.

X-15 No. 3 Being Rebuilt

Repairs Required After Test Stand Explosion -- By early June development of the final design engine, the 57,000-pound-thrust unit had progressed almost to the flight stage. However, on June 8, while undergoing final ground tests by the contractor, North American Aviation, Inc., the fuel and hydrogen-peroxide tanks in X-15 No. 3 (the airplane in which the XLR-99 engine had been installed), exploded on the stand. Pilot Scott Crossfield was seated in the cockpit of the airplane, but was uninjured when the blast hurled the forward section 20 feet away. The aft section, containing the engine, remained secured to the stand and was almost completely destroyed.

The XLR -99 engine had been tested many times before, but additional ground tests were required after the engine was mated to the aircraft, to determine a variety of factors such as vibration levels, the ability of the pilot to stop and

restart the engine, and the rocket's automatic shutdown system (the engine is equipped with detectors, or sensors, that cut off the power in case of excessive heat or vibration).

The accident has caused some serious delays in the program: 1) the first flight with the XLR-99 engine was delayed by two months; 2) delivery of an airplane in the final configuration to the Government was also delayed at least three months; 3) the availability of the X-15 No. 3 for use in the flight test program has been set back about 16 months; and 4) the Government program now under way with X-15 No. 1 was delayed about two months.

Final Air Force approval for reconstructing X-15 No. 3 was granted about September 1, and the contractor has started work, which will take an estimated 11 months and cost about \$4 million. After reconstruction is completed, a six-weeks period of ground testing will be required before the airplane can be delivered to the Government about October 1, 1961.

Status of Major Program Objectives

In addition to the aspects of the X-15 program previously discussed, the following major objectives are of interest: flight control at very high altitude; atmospheric exit and entry techniques; terminal guidance; aeromedical aspects; and landing load research. A brief summary of each major objective and related areas of interest is given below:

Flight Control at Very High Altitude -- As yet, there has been no evaluation of the reaction controls of the X-15 at high altitude. The Government flight program is being conducted without using this system. However, in the record-altitude flight to 136,500 feet, good control was achieved (minimum dynamic pressure of about 10 pounds per square foot was attained) and there were no significant piloting problems, despite the absence of reaction controls.

Valuable information on reaction controls is being obtained on a supporting project -- tests have been made of a reaction control system on an F-104A airplane. Results so far cannot be applied directly to the X-15 program, but participating pilots agree that the experience they have obtained in this first high-altitude use of reaction controls is quite valuable.

Atmospheric Exit and Entry Techniques -- The techniques employed in completing the record high-altitude flight were, of course, quite simple in comparison with those that will be required for exit and entry on later missions to 250,000

feet and higher. However, an evaluation of the flight techniques used, augmented by wind-tunnel and theoretical studies, indicate no severe problems are to be expected. The control characteristics of the X-15 with the "damper system" (automatic equipment that prevents excessive oscillations or over-response to control) have generally been rated very good by the test pilots. Wind-tunnel and theoretical predictions have in general been substantiated by the flight tests. A fixed-base simulator, programmed on the basis of wind tunnel data, has proved an invaluable tool for planning flights and training pilots.

Terminal Guidance -- The fixed base simulator has given excellent training and preparation to the test pilots thus far, in making flights over distances of as much as 100 miles from the landing site. On the basis of landing experience to date, a composite landing pattern is used that combines the best features of a conventional circular approach and the straight-in pattern proposed by the Ames Research Center. The pattern begins with a circular approach at about 300 mph (indicated air speed), with the rate of descent planned so that the pilot will have maximum permissible altitude in the final straight-in leg. This is followed by predetermined "flare control" procedures -- that is, the airplane descends in a smooth curve, making a transition from a steep descent to a direction of flight substantially parallel to the landing surface. In recent flights, the X-15 has been brought down in this phase at a speed of between two and four feet per second, and touchdown has generally been within 1,000 feet of the desired point.

To prepare the pilots for the low lift-drag characteristics of the X-15, practice approaches were made in an F-104A airplane with somewhat similar handling qualities. The use of this airplane has enabled the pilots to maintain their proficiency even when long periods occur between X-15 flights.

Aeromedical Aspects -- To date, physiological measurements made on the test pilot during flight have been of a relatively limited nature. In the near future, more complete measurements will be made. Additional equipment for detecting various kinds of radiation, cosmic rays, etc., will be carried inside and outside the X-15 on later flights.

Landing Gear Research -- Research on the stresses and strains encountered by the X-15's landing gear (described in Chapter 13 of NASA's Second Semiannual Report to Congress) has continued. During the period data were obtained on 17 landings, at various rates of descent of up to 9.5 feet per second at touchdown, and at ground speeds from 167 to 274

miles per hour. The results indicate that the highest forces and strains on the main gear (skids located well back on the airplane, behind its center of gravity) occur when the nose-gear touches down. It was also found that the strain on the landing gear is affected more by the airplane's attitude or angle than by the sinking speed or rate of descent at the time of touchdown. The high drag of the main-gear skids has been found to give more than adequate directional stability.

NASA SUPPORT OF THE DYNA-SOAR PROGRAM

The Dyna-Soar-I Program

A projected manned orbital glider under development as a joint program between the Air Force and NASA -- has reached the stage at which many design and hardware features have been specified, and operational techniques are being developed. Molybdenum has been chosen as the material to be used for most of the glider structure. Areas that will be subjected to high aerodynamic heating will be coated with ablation material.

A winged glider, the Dyna-Soar, will be carried into orbit by a modified Titan launch vehicle. Unlike the Mercury capsule (see Chapter 3, Manned Space Flight, pp. 23-24). Dyna-Soar will not make sea landings, but will come down at conventional landing fields. Boeing Airplane Co., Seattle, Wash., under contract will build 11 vehicles for ground tests, unmanned test flights, and piloted flights.

Program Has Two Phases -- The program will begin with air drops of the glider from a mother craft (in much the same way that the X-15 research airplane is dropped), followed by long-range suborbital launchings by a modified Titan-J launch vehicle.

Role of NASA -- NASA research in support of the Dyna-Soar is directed toward providing the Air Force with technical assistance in all aspects of the Dyna-Soar project.

Glider Requirements -- Briefly stated, the requirements for the glider configuration are: 1) it must be aerodynamically stable and controllable throughout the range from orbital speeds to subsonic landing speeds; 2) it must be built to withstand the intense heat generated by air friction during atmospheric entry; and 3) it must be structurally sound, to withstand the strains and pressures imposed upon it during launching and all phases of flight. In combination with the launch vehicle, the over-all unit must be aerodynamically compatible, stable, and controllable.

Studies in Progress -- To aid in selecting a final configuration that will meet these requirements, NASA is carrying out extensive investigations over the anticipated speed range. Studies are in progress on the effects of changes in geometry on stability and control and aerodynamic heating -- for example, the diameter of the leading edge of wings, the amount of sweep (angling back of the wing in relation to the body), the dihedral angle (a tilting upward or downward of the wing as it extends outward from the body), the body shape, and the vertical tail shape, to mention a few. Some of the NASA investigations are specifically requested by the Air Force; others are more general research projects that have direct application to the Dyna-Soar program.

Low Speed Dynamic Characteristics -- The dynamic characteristics of the glider at the relatively low speeds at which it comes in for a landing will be determined at the Langley Research Center. Using the full-scale wind tunnel, dynamic stability and control characteristics will be determined with a flying (remotely controlled free-flight) model operating under its own power. Also at Langley, the Radio Control Test Unit will be employed, using a 1/5-scale model (nonpowered, radio-controlled) ballasted to simulate dynamic characteristics of the full-size unit. The model will be dropped from a helicopter at an altitude of about 3,000 feet, to study dynamic stability characteristics through the entire flight range, with emphasis on "high angle of attack" performance. At NASA's Ames Research Center, the 12-foot Pressure Tunnel is being employed to measure the effects of many changes in the shape of configuration of the glider at Mach numbers from .25 to .50. Tests are also under way at this facility to find out how ground winds affect the launch vehicle glider combination while it is on the launching pad.

Investigations at Transonic Speeds -- At the speed range approximately that of sound (Mach 1), an investigation was conducted in the Langley 8-foot wind tunnel to determine the static ("at rest") aerodynamic characteristics of the glider-launch vehicle combination, using several different fin configurations on the launch vehicle. Information was obtained on the best sizes and shapes of fins on the vehicle to give good stability, both longitudinal and lateral. Similar tests are under way at the Langley 16-foot Transonic Tunnel to learn more about stability and control of the glider alone. The effects of changes in size and shape of the

vertical fin, the body, wing camber*, and elevon** geometry will be investigated. Over the speed range from Mach .6 to Mach 3.5 (high subsonic to supersonic speeds), the stability and control characteristics of the launch vehicle glider combination and the glider alone are being investigated at the Ames Unitary Plan wind tunnels. Tests in this facility are under way.

Tests at Hypersonic Speeds -- In the hypersonic speed range (more than five times the speed of sound), an investigation is in progress at Langley on the problems of instability at low angles of attack (0° to 15°), and the effect on stability of various nose and canopy shapes. Tests are being carried out in the Langley 11-inch hypersonic wind tunnel, at a Mach number of 9.6. The effects of vertical fin size and the angle of the fins to the airstream are also being investigated. Other factors under study include the size and shape of lower wing surfaces, fins, etc., and the manner in which they affect aerodynamic heating characteristics. The most promising configurations will be studied at a Mach number of 18 at a later date. A program of atmospheric entry studies at speeds up to Mach 21 (about 20,000 feet per second) is being pursued at Langley. The program will also have application to the Dyna-Soar project.

Flight Research Center Participation in the Dyna-Soar Program

Participation of NASA's Flight Research Center (FRC), Edwards, Calif., in the Dyna-Soar program consists of engineering, research, developmental, and planning effort in two general categories: 1) air vehicle systems development; and 2) flight-test operations. The Center is conducting specific and general research in development programs; it is providing research, development, and planning efforts for specific Dyna-Soar systems, and keeping in close touch with the requirements for the systems. FRC cooperates closely with the Air Force Dyna-Soar Weapons Systems Project Office. Engineering personnel have been assigned as members of Joint Government-Contractor Technical Groups, to the Dyna-Soar Systems Development Test Force and to the Instrumentation Development Team.

* The curvature of an airfoil or wing from front to back (leading edge to trailing edge) in comparison with a straight line (chord) joining the two edges.

** A control surface that functions both as an elevator and an aileron (flap).

Air Vehicle Systems Support -- FRC effort in the area of air vehicle systems development has consisted of monitoring and evaluating the launch vehicle, glider, and sub-systems designs. The Center expresses concurrence with contractor concepts and proposals, or recommends alternate approaches to the Dyna-Soar Weapons Systems Project Office, which is charged with technical direction of the program. FRC has devoted considerable effort to establishing flight-test and flight research data requirements and to specifying and developing concepts for the necessary specialized instrumentation and data system for the glider.

Flight Test Operation -- Major FRC efforts to date have been to establish Dyna-Soar Step I flight testing objectives, to develop a flight-test concept for a hypervelocity glider carried by a modified Titan vehicle, and to establish the detailed flight-test techniques that must be used. These latter studies are being conducted in close cooperation with Air Force and Contractor personnel. The supporting flight test program currently consists of such activities as reaction control, infrared sensing, and low lift-to-drag ratio landing program on the F-104 airplane, and practically all facets of the X-15 program.

Investigation of Landing Problems

There are three principal requirements for the Dyna-Soar landing gear system: 1) the skid material must be able to withstand the high aerodynamic heating encountered during entry; 2) the skids must be designed so that the vehicle maintains its stability during all phases of the landing;* and 3) the glider must be able to stop within the limits imposed by the landing fields down range from Cape Canaveral; thus the skid materials must have a high enough friction coefficient to slow and stop the vehicle within a distance of 8,000 feet. (Available runways are 10,000 feet long, allowing a 1,000-foot over-run at each end.) These problems are being investigated at the Langley Research Center's Landing Loads Track. On the basis of tests of numerous materials and shapes, wire brush material has been selected for the main skids, and a cermet (mixture of ceramic and metal) for the nose skid. With this arrangement, a full-size model of the Dyna-Soar system will be investigated. Aerodynamic loads will be programmed into the simulation during landing tests, so that landing loads and stability can be determined using full-scale hardware.

* To accomplish this, the nose skid must slide more easily (have a lower friction coefficient) than the two main rear skids.

Air Vehicle Systems Development

During the next two years, FRC will devote an increasing effort to assure the design and procurement of a usable and useful Dyna-Soar vehicle. In parallel with this effort, vehicle flight characteristics and flight environment will be predicted and assessed. Specific research and development flight tests in direct support of the development of the Dyna-Soar glider systems will be conducted both independently of, and as part of, joint NASA-USAF-contractor test programs.

Research Center Direct Support

ADVANCED RESEARCH APPLIES TO MANY PROGRAMS

Earlier chapters of this report have detailed NASA's progress in specific aeronautical and space programs. Facilitating this progress, however, has been much broadly based research -- some of it quite general, some of it applied -- in direct support of these programs, under the direction of NASA's Office of Advanced Research Programs, which includes the Ames, Lewis, Langley, and Flight Research Centers originally established by the National Advisory Committee for Aeronautics (NACA), NASA's predecessor agency.

The Office of Advanced Research Programs works closely with the Offices of Launch Vehicle Programs and Space Flight Programs to provide research and technical assistance essential to their projects. It also furnishes research assistance to the military services, other Government agencies, and to industry. This research, which under NACA was directed almost entirely to the technical requirements of civilian and military aircraft, is now directed to the needs of space activities as well.

Typical examples of direct support of research follow.

Project Scout

Vehicle Is Langley Concept -- The concept of the Scout was originated in 1958 by scientists and engineers at Langley Research Center. Langley is systems manager for the program, with responsibility for the airframe, guidance and control systems, and rocket engine contracts. The center also designed, developed, constructed, and installed Scout telemetry systems.

Design Data Obtained -- At various stages in Scout development, design data on aerodynamics, flutter, aerodynamic heating, response to controls, and structural behavior were obtained by analytical and experimental investigation. During the past six months, the first test vehicle was delivered to Wallops Station, assembled, put through a thorough laboratory check, and launched successfully (see Chapter 7, Launch Vehicles and Launch Operations, pp. 75-77). A second test vehicle is being assembled and checked out;

work is 90 percent complete, and on schedule. Fabrication of components for the third and fourth vehicles has begun and is also on schedule.

Project Centaur

Propellant Tank Insulation Studies -- Centaur, like all launch vehicle stages using high-energy cryogenic (very low temperature) propellants, requires insulated tanks to keep "boil-off" losses as low as possible, both on the launching pad and during flight through the atmosphere. At Lewis Research Center, several nonmetallic insulation materials that can be bonded to the propellant tanks and sealed against air penetration have been investigated. Experimental data were obtained not only on insulation properties of these materials, but also on structural strength and ablation characteristics at the high temperatures of aerodynamic heating encountered while the vehicle is escaping the atmosphere. At Langley Research Center, wind tunnels have been utilized to investigate the flutter characteristics of the Centaur's hydrogen tank insulation material.

Uninsulated Tank Experiments -- In closely related work at Lewis, another approach is being studied, in which the hydrogen tank is not insulated. This approach involves filling the tank so that a coating of ice and frost forms on the walls and acts as an insulating medium. Improper techniques will cause liquid air, rather than frost, to form. A method of filling has been worked out, and although the frost insulates only about one-fourth as well as the cork sheet-board used in most insulated tank tests, the results appear promising. A potential advantage of frost over cork insulation is that it ablates during the climb through the atmosphere and lightens the vehicle during the final part of the flight. Further analysis and experiments are planned.

Studies of Propellants During Weightlessness -- At Lewis, a program is under way to assess what the condition of the propellants in Centaur tanks will be after long coasting in space. Since gravity will no longer affect the liquid, its location in the tanks will be controlled almost entirely by surface tension forces. In the case of hydrogen, at present it is impossible to predict to any degree of certainty whether the liquid will mass at the center of the tank or become distributed around the inside wall. A series of experiments are under way, employing an airplane and Aerobee sounding rockets. Techniques are similar to those employed in weightlessness experiments for Project Mercury (see Chapter 5 of NASA's Second and Third Semiannual Reports to Congress), in which a ballistic trajectory is flown.

During the "over the top" portion of the curve, there are short periods of weightlessness. The experiments should help clarify areas of uncertainty and aid in obtaining greater vehicle reliability.

Ground Operations Problems -- Another area of Lewis research is the investigation of problems associated with ground operations for liquid hydrogen-fueled vehicles such as Centaur. Methods of loading and "topping" (adding fuel to replace "boil-off"), venting, unloading and "purging" (Clearing tanks and lines after unloading), are being studied, using an insulated, flight-weight tank. Techniques and routines have been established that appear adequate to satisfy the requirements of Centaur launch operations. During these experiments, it was found that the cork insulation -- mentioned earlier -- will prevent excessive hydrogen boil-off when delays in preparing for launch are moderate. Techniques for applying the insulation to the tank, however, are not entirely satisfactory, and additional work is required.

Fluctuating Pressure Tests -- At Ames Research Center, fluctuating pressures on a model of the Centaur vehicle were measured in the 14-foot transonic wind tunnel which simulates acceleration through the transonic speed range. Experimental results obtained provided a basis for the structural design of the vehicle.

Studies of Base Heating -- As discussed in Chapter 15 of NASA's Second Semiannual Report to Congress, hot exhaust gas recirculating around the base of a rocket vehicle can raise it to very high temperatures, and in some cases may even set the engine compartment on fire. (Previous single-engine tests showed that the same effect can be caused by combustible exhaust products from the propellant pumps.) An investigation is in progress at Lewis to determine how severe the base heating problem will be for the full-scale Saturn launch vehicle, and how excessive heating can be alleviated or avoided. A 1/27-scale model of the Saturn first stage is being subjected to a wide range of simulated flight speeds and altitudes in the 8- by 6-foot supersonic wind tunnel: speeds from 1/10 to twice the speed of sound (Mach 0.1 to Mach 2.0), and altitudes from sea level to about 35,000 feet. The scale-model rockets, using the same liquid-oxygen and kerosene propellants as will the Saturn, are fired while the tunnel is operating. In this manner, the heat at the base region can be determined, and the data obtained can be applied to insulating the aft portion of the vehicle or to modifying its shape to keep base heating on the full-scale Saturn to acceptable levels. In tests to date, base temperatures ranging from 400°F to 1,340°F have

been measured, depending on the propellant mixture ration in the engines and the shape of the model. Effects of other variables are also being investigated.

Multiple Studies at Langley -- At Langley, a number of investigations were started during the report period, including:

1) Development of a system for recovering the Saturn first stage after launching and stage separation. Experiments employ air drops of small scale models which simulate the dynamic characteristics of the Saturn first stage.

2) Experiments to measure response of Saturn vehicles to ground winds while on the launch pad. The tests employ a transonic wind tunnel and scale models that simulate the dynamic and elastic (the skin of even the full-scale launch vehicle will be extremely thin and flexible) characteristics of the Saturn.

3) Studies of vibration characteristics of the Saturn C-1 cluster, including the effects of fuel sloshing and aerodynamic pressures. A 1/5-scale model and a 1/40-scale model are being used.

4) Investigation of static and dynamic stability of Saturn, including aeroelastic effects* and measurements of the forces exerted on the nozzle in the unitary plan wind tunnel.**

5) Investigation of rocket exhaust jets at simulated high altitudes. This is an analytical (mathematical) and experimental investigation using nozzles of less than one inch in diameter, with the propellant exhausting into a near vacuum -- an absolute pressure of less than 5/10,000 of an atmosphere.

* Flexing caused by aerodynamic forces, and the changes such flexing causes in aerodynamic characteristics.

** One of five NASA wind tunnel installations built and operated primarily to meet the needs of industry, the military services, and other Government agencies for testing supersonic aircraft and missiles and their components.

Project Echo*

Sphere Is Langley Development -- The 100-foot diameter inflatable sphere used in the Echo Project was developed at Langley, and the spheres for all suborbital and orbital tests were assembled and checked out there. Suborbital tests of Echo were from Wallops Station.

Rigidization Study -- Techniques developed by Langley of rigidized 12-foot satellites are forming the basis of contractual work on rigidized 100-foot satellites.

Project Nimbus

Stabilization and Control Development -- Ames Research Center is providing technical support to Project Nimbus, the meteorological satellite to follow TIROS. The Center is carrying on analytical and experimental work, after having assisted in writing specifications for the project and evaluating contractors' proposals. Experimental development of the fine control pointing system of Nimbus is under way. A control system, employing components that will be employed in the final satellite, has been mounted on a platform supported on an air-bearing gimbal (a device that can move in various directions with almost no friction, simulating conditions in space) and is being tested.

Project Mercury

Wind Tunnel Tests -- At the Ames Research Center, supersonic and transonic wind tunnel tests were made to determine the stability of the capsule in combination with the escape rocket tower or pylon (described in Chapter 5, NASA Third Semiannual Report to Congress), and the modified Atlas-D launch vehicle. Test results were forwarded to the Space Task Group, to check the possibility of a collision between the launch vehicle and capsule during an abort. Other stability tests of the capsule alone were made at Mach numbers up to 14.5 in the ballistic range.

High Altitude Simulation Tests -- The Mercury capsule is fitted with three solid-propellant rocket systems, separate and distinct from the main launch vehicle propulsion system: 1) The Escape Rocket System, which hurls the capsule away from the launch vehicle if the latter malfunctions.

* Details of suborbital tests and of the Echo I launching appears in Chapters 2, 7, and 9.

2) The Posigrade Rockets, which separate the capsule from the launch vehicle when orbital altitude is reached. 3) The Retrograde Rockets, which slow the capsule when it is time to start the descent from orbit.

The high-altitude performance of all three systems was evaluated in a large vacuum chamber facility at Lewis. The Escape Rocket System was fired four times, with excellent results. The Posigrade and Retrograde Systems were evaluated in the chamber on a special device that measures the direction and force of the thrust. Since thrust misalignment of these systems would make the capsule tumble, it was necessary to evaluate them carefully under high-altitude conditions. A special aligning device, used to install the rockets, was found to produce satisfactory results.

Capsule Preparation -- In June 1960, the Langley Research Center completed an investigation in which a Mercury capsule was instrumented, calibrated, and put through environmental testing in preparation for structural integrity tests scheduled to be made at Cape Canaveral. McDonnell capsule No. 3, scheduled for a Little Joe shot has undergone noise testing with complete life-support equipment installed and operating; these tests, completed in September 1960, indicated that both the life-support system and the capsule will function properly under the noise levels anticipated.

Tracking and Ground Instrumentation -- Langley is responsible for tracking and ground instrumentation for Project Mercury, described in Chapter 3, Manned Space Flight.

Other Assistance -- Langley has also cooperated with the Space Task Group in fulfilling special requests for the Mercury Project.

Orbiting Astronomical Observatory

Preliminary Work in Progress -- Ames Research Center is participating in preparing specifications for an orbiting astronomical observatory satellite (see Chapter 4, Scientific Satellites and Sounding Rockets), and helping to evaluate proposals and select a contractor. The Center is also carrying out a program of analytical studies and experimental development leading to systems for orienting and stabilizing the satellite precisely.

Project Trailblazer

Cooperative Project* -- Langley is cooperating with the Massachusetts Institute of Technology's Lincoln Laboratory, Millstone Hill, N.H., on Project Trailblazer. The object of the two-part program is to improve methods of detecting bodies entering the atmosphere at high velocities; such bodies become surrounded by a sheath of ionized particles which can be detected by radar, giving the effect of a much larger object.

Trailblazer I -- The present six-stage test vehicle launches a five-inch sphere which can be tracked when it enters the atmosphere. Two Trailblazer I spheres were fired in August, 1960, with excellent results; the first vehicle contained a five-inch titanium sphere entry object; the second, a five-inch aluminum sphere coated with phenolic nylon material. Both vehicles functioned properly and were tracked by Wallops Station (where the launch took place) and by the Lincoln Laboratory. Two more units will be fired in this series.

Trailblazer II -- The next part of the program will employ vehicles having four stages, and a 15-inch sphere weighing about 15 pounds. During the period, contractors' proposals for design and fabrication were evaluated by Langley. A contract was awarded in September by the Lincoln Laboratory to the Atlantic Research Corp., Space Vehicles Group, Pasadena, Calif.

Micrometeoroid Satellite

Langley Develops Payload -- Langley Research Center is developing a micrometeoroid satellite (see Chapter 4, Scientific Satellites and Sounding Rockets, p. 43) to learn more about the impacts of micrometeoroids on spacecraft. Authorization was approved in July 1959, and \$150,000 was transferred to Langley the following month to procure materials, electronics and equipment for construction, testing, installation, and data reduction.

* Lincoln Laboratory has a contract with the Advanced Research Projects Agency (ARPA) of the Dept. of Defense to study numerous phases of ICBM systems. The NASA cooperative program is part of this contract. Lincoln Laboratory pays for all hardware, rockets, and electronic components of the vehicles. It will also pay for the design of the advanced vehicle, Trailblazer II.

This payload is scheduled to be launched early in 1961 on Scout No. 4. Design work is essentially complete; telemetering development is on schedule; beryllium-copper pressure cells are being fabricated; and satellite components are being tested in the recently installed high-vacuum facility at Langley.

Construction and Equipment *

Between April 1 and September 30, 1960, NASA expenditures on construction and equipment totaled about \$50 million. Principal projects follow.

AMES RESEARCH CENTER, MOUNTAIN VIEW, CALIF.

3.5-Foot Hypersonic Wind Tunnel

In September, NASA began final acceptance tests of the 3.5-foot hypersonic wind tunnel, constructed at a cost estimated at \$11 million. The tunnel will test scale-model aircraft and components at pressures as high as 3,000 psi and temperatures as high as 4,000°F. to simulate steady, level flight at hypersonic speeds.

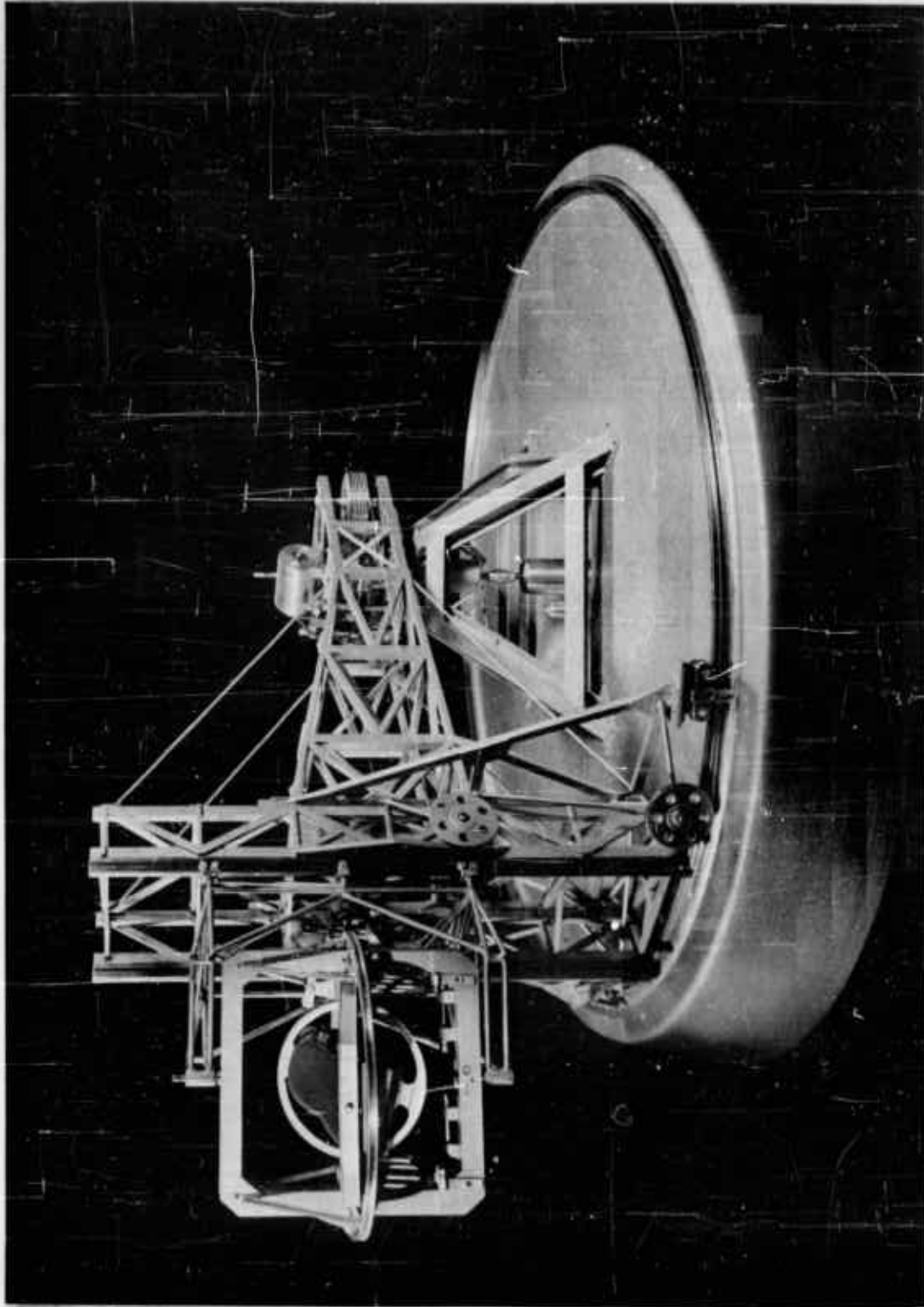
12-Inch Helium Wind Tunnel

The 12-inch hypersonic helium wind tunnel, completed during the period at an estimated cost of \$1,585,000, was also undergoing acceptance testing. Helium gas under high pressure released into the tunnel simulates speeds from 12 to 20 times that of sound in air for four minutes, a relatively long test run. After each test, the helium is recovered from the tunnel for re-use. The tunnel will be used to test models of spacecraft.

Flight Research Laboratory

Laboratory space has been increased and a five-degree-of-freedom motion simulator built. The simulator can duplicate for the astronaut or pilot the conditions he would

* Progress at Minitrack and Deep Space tracking stations is described in Chapter 6, Tracking and Data Acquisition, pp. 67 ; at Mercury tracking stations in Chapter 3, Manned Space Flight, pp. 30 .



The Ames Research Center five-degree-of-freedom simulator. At left is the pilot's cockpit which can roll, pitch, and yaw while the entire assembly swings around the circular track and moves up and down the vertical rails. The simulator will test pilot control of spacecraft during entry.

encounter during entry into the atmosphere at moderate speed -- including the gyrations of the spacecraft and deceleration forces of 6 or 7g. Estimated total cost is \$990,000. The simulator is illustrated on page 174.

Hypervelocity Research Laboratory

The building has been completed and occupied, and about half of the equipment has been installed. This laboratory will provide facilities for studying phenomena encountered during hypersonic flight, such as high-temperature gases, magnetogasdynamics, interaction between high velocity particles, and properties of matter in solid and liquid states. Estimated cost is \$1,145,000.

Mass Transfer Cooling and Aerodynamics Facility

NASA has completed designs and specifications for this wind tunnel which is expected to cost about \$4 million. The facility will be able to simulate on models the heating rates and aerodynamic buffeting encountered by spacecraft during steep entry into the atmosphere. Because it will be able to run at least 10 minutes per test, the facility will be particularly useful for studying ablation cooling in detail.

Major components are a 15,000 psi air-storage system, an electric-arc heater that can produce 18,000°F. temperatures, and a steam-driven ejector vacuum system.

Centrifuge Facility Modifications

Design of special equipment including an advanced analog computing system was begun. Improvements were being made in the drive system of the centrifuge. Estimated cost is \$980,000.

Data Reduction Center

Ames will use this center to process research data and to solve complex theoretical problems. Building design is complete and construction in progress. The center will provide 43,500 square feet of floor space for offices and high-speed digital computers. Estimated cost is \$2,305,000.

FLIGHT RESEARCH CENTER, EDWARDS, CALIF.

X-15 Research Airplane Program Facilities

Installation and acceptance tests were completed on the analog computer that will operate the X-15 Flight Guidance Simulator. Delivery of the simulator was rescheduled from July 1960 to November 1960 pending flight of the X-15 research airplane with its new XLR-99 rocket engine. The simulator will be used in planning flights and training pilots. Estimated total cost of the computer and simulator is \$350,000.

Construction has begun on the Terminal Guidance Facility, estimated cost of which is \$1,425,000. The facility will provide a microwave link for transmission to the Flight Research Center of data acquired during X-15 flights. These data will be used to monitor the X-15 in flight, to assist the pilots of chase aircraft in their observations, and to guide the X-15 pilot to an emergency landing site, if necessary.

An existing building is being modified to house these facilities.

Test Stands for F-1 Engine Development

The F-1 is an advanced rocket engine, under NASA development, which will be able to generate about 1.5-million pounds of thrust. A test stand, being built for the F-1, has been 70 percent completed. Estimated cost is \$15 million.

One of two existing test stands has already been converted to F-1 use; another is 90 percent converted.

NASA has allocated \$1,340,220 for construction of a 2,000-ton liquid-oxygen storage and transfer system for the new test stand.

GODDARD SPACE FLIGHT CENTER, GREENBELT, MD.

NASA occupied three buildings at Greenbelt during the period and began studies on a Payload Test Facility (Building No. 7) and a Manned Satellite Projects Laboratory (Building No. 8). Estimated costs of these structures are \$3,555,000 and \$4,636,000, respectively.

Personnel and equipment of the center's headquarters, business, and technical services offices have moved into Building No. 1, the Space Projects Building. A portion of the Space Science and Satellite Applications Group is housed

in Building No. 2, the Research Projects Laboratory. Construction of Building No. 1 and No. 2 was completed during the period. Cost is about \$3,250,000, exclusive of research equipment.

Building No. 3, the Central Flight Control and Range Operations Building, was 50 percent complete as the report period ended. The Mercury and Minitrack satellite tracking control centers have been transferred to this building. Estimated cost is \$3,830,000 including research equipment.

Forty percent of Building Group No. 4, comprising the central power plant and service shops, has been completed. Sixty percent of the design for Building No. 5, the Instrument Calibration and Installation Laboratory, has been accomplished. Estimated cost is \$3,700,000 including research equipment. Building No. 6, the Space Sciences Laboratory, has been designed and advertisements for bid distributed. Estimated cost is \$5,470,000 including research equipment.

JET PROPULSION LABORATORY, PASADENA, CALIF.

Laboratory and Engineering Facilities

Addition to Guidance Laboratory 161 -- A three-story addition to the Guidance Laboratory was designed and is being built. It will have 45,000 square feet of laboratory and office floor space and cost about \$1,116,000.

Plant Services Engineering and Shop Building -- Construction has begun on this two-story building, which will have 16,000 square feet of floor space. Estimated cost is \$180,000.

Vehicle Assembly Building and Environmental Testing Laboratory -- About one-fifth of this facility has been constructed. It will provide 37,500 square feet of open hangar space, offices, and laboratories. Estimated cost is \$1,080,000.

Solid-Propellant Facilities -- These facilities, including storage magazines for hazardous materials, test cells, a control building, and a processing laboratory, are being designed. They are planned for a new 60-acre area north of the existing built-up section of the laboratory grounds. Estimated cost is \$1,091,300.

Liquid-Propellant Facilities -- A liquid-propellant test cell and control building are being designed for the same area. Estimated cost is \$374,990.

Support Facilities

Administrative Services Building -- Thirty percent of a two-story addition to the Administrative Services Building has been completed. The addition will have 15,000 square feet of floor space. Estimated cost is \$298,000.

Reports and Periodicals Building -- Designs are being made for a building with 17,000 square feet of floor space for offices, workshops, and laboratories. Estimated cost is \$400,000.

Utilities -- Thirty percent of a 3,000-kw power substation and transformer station for the new seven-acre south area was constructed. Estimated cost of the two units is \$175,000. Construction of distribution lines for electricity, gas, water, sanitary sewers, and storm sewers in the south area is 20 percent complete. Utilities to support planned laboratory and other facilities in the south area were being designed as the report period closed.

LANGLEY RESEARCH CENTER, HAMPTON, VA.

20-Inch Variable Mach Blowdown Tunnels

Two 20-inch variable-Mach blowdown tunnels* have been constructed at an estimated cost of \$1,893,669. NASA will employ them for tests of models traveling at simulated hypersonic speeds. One tunnel has operating ranges up to Mach 6 (six times the speed of sound); the other, operating speeds of Mach 1.5 and 4.5.

Eight-Foot Transonic Pressure Tunnel

This tunnel has been modified, at an estimated cost of \$1,297,844, extending its range to Mach 1.2. The added equipment is also employed as the main drive of the two-by-two-foot Mach 7 wind tunnel.

* Wind tunnels in which stored compressed air or other gas is allowed to expand in a stream through a section in which models are placed.

26-Inch Transonic Pressure Tunnel

A 20-inch test section mounted on the tunnel has extended its range from Mach 1.4 to Mach 4.0. The section, which costs about \$347,092, operates with existing controls, air supply, and exhaust systems. It will be used to study the effects of aerodynamics on elastic structures.

19-Foot Pressure Tunnel

Improvements in the 19-foot pressure tunnel include newly installed power supply equipment, test section, and freon handling equipment. The range of operating speeds and temperatures has been increased, permitting extensive study of the dynamics of spacecraft and aircraft. Estimated cost is \$9,615,474.

Structures Research Laboratory

A 10,000-kw electrical power system has been installed. It permits structural components of aircraft and spacecraft to be tested at the rapid heating rates and high temperatures they would encounter during flight at supersonic and hypersonic speeds.

Other Projects

Preliminary design studies have been started on a hypersonic aerothermal dynamics facility and a dynamics research laboratory. The facility will simulate the environment encountered by spacecraft entering the atmosphere. The laboratory will be employed to study structural dynamics and flutter of launch vehicles and spacecraft.

LEWIS RESEARCH CENTER, CLEVELAND, OHIO

Nuclear Propulsion Facilities

The modified Component Research Facility for Nuclear Propulsion at Plum Brook, Sandusky, Ohio, was tested for final acceptance. Lewis will employ the facility for research in nuclear propulsion problems -- such as radiation, fluid flow, heating, and shielding -- as well as in problems arising from use of reactors to generate auxiliary electric power (for example, SNAP-8, described in Chapter 8, Propulsion and Nuclear Energy Applications for Space, pp.108.)

An addition to the Materials and Structures Building has been erected to house a zero-power reactor, construction of which is progressing. Estimated cost of the structure and reactor is \$605,000. The reactor, a full-scale replica of the core, reflector, and test facilities of the powerful Plum Brook reactor, operates at low power (usually less than one watt) and at room temperature. It cannot be used as a heat source. It will be employed as a source of neutrons to study reactor physics such as nuclear shielding, the basic properties of neutron sources, the effects of reactivity, stresses imposed upon materials by nuclear propulsion, and related problems.

Propulsion Systems Laboratory

Modifications of the Propulsion Systems Laboratory have been completed to provide a fuel system for testing high-energy rocket engines at simulated high altitudes.

Rocket Systems Research Facility

About 85 percent of this facility being built at Plum Brook has been completed, and one of its units is operating. Lewis will utilize the facility to study propellant control and pumping, multistage hydrogen pumps, and turbopumps, and to test large models of rocket engines and instrumentation for research vibration tests.

Supersonic Wind Tunnel

An air heater for the Lewis 10 x 10 foot Supersonic Wind Tunnel has been more than half completed. The heater emits a jet of hot compressed air, similar to a rocket exhaust, increasing the simulated altitude from 150,000 to 250,000 feet, and making it unnecessary to heat the entire air supply for the tunnel.

Hypersonic Rocket Propulsion Facility

Seventy percent of this facility has been completed. Its chief features are a wind tunnel, two feet square in cross section, which can be heated to 15,000°F. The facility can generate high-power electricity and strong magnetic fields for containment of plasmas (see Chapter 11, Research Primarily Supporting Space Activities, pp. 143). It has a

liquid-helium system with a pumping capacity of about 26.5 gallons per hour which makes it useful for experiments requiring a low-temperature and low-density environment. The facility will be employed for aerodynamic research and testing ion and plasma engines.

Materials Research Laboratory

The laboratory was modified at an estimated cost of \$2,120,000. New equipment includes machines to test the mechanical properties of materials at cryogenic (intensely cold) temperatures and vacuum metallizing equipment for applying coatings to refractory (resistant to heat and fusion) materials.

Rocket Engine Research Facility

This facility will comprise three test stands in the Cleveland area and one test stand at Plum Brook.

Cleveland -- Three rocket test stands, each capable of handling about 5,000 pounds of thrust, have been completed. These stands fire either vertically or horizontally.

Plum Brook -- About ten percent of the fourth test stand at Plum Brook has been completed. This unit will permit testing of toxic propellants such as fluorine and be able to accommodate about 100,000 pounds of thrust for as long as five minutes. It will fire vertically. The stand includes equipment to duplicate within the test engine capsule (a compartment in which an engine can be sealed) the very low atmospheric pressure encountered at an altitude of 150,000 feet.

Ion and Plasma Jet Facility

Sixty percent of the design and ten percent of the construction of this facility have been completed. Under simulated space conditions, it will test two-million-watt ion engines.

Contemplated Construction

Under design at Lewis Research Center are a Basic Materials Laboratory for research on new materials with space flight applications, and an Energy Conversion Laboratory to

test processes and equipment for power generation and energy conversion. Estimated costs are \$4,050,000 and \$5,050,000, respectively.

MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALA.

Nearly all construction at Marshall is in support of Project Saturn, the development of a clustered-rocket launch vehicle with about 1.5-million pounds of thrust.

Dynamic Test Stand

Construction has begun on a 204-foot steel tower and related equipment for vibration testing of Saturn and its upper stages. Estimated cost is \$773,000.

Static Test Stand

NASA received several proposals from industry for criteria development and design of the static test stand for Saturn. Cost of the initial phase will be about \$10,800,000.

Pressure Test Cell

Design of a building that will provide 21,000 square feet of floor space for pressure-testing Saturn is 90 percent complete. Estimated cost is \$650,000.

Extension to Assembly Buildings 4705 - 4706

Design was 90 percent complete for enlarging the Missile Assembly Buildings to permit assembling several Saturns at a time. The additions will total 76,600 square feet of floor area and will cost about \$2,500,000.

Transportation Facilities

Reinforcement of the roadway and bridge between the Saturn test area and the Tennessee River is 60 percent complete. Roads in the Industrial Area have also been strengthened and obstructions removed to make it easier to transport the huge Saturn vehicle from one area to another. A concrete ramp by the river to be used for loading Saturn on its transport barge is 60 percent complete. Total estimated cost is \$354,000.

Other Projects

Floors of the Check-Out Building have been reinforced to bear the weight of the Saturn launch vehicle. A fueling-test facility has been installed in the test area. Other buildings have been modified to provide space for supporting activities previously furnished by the Army. Under design are additions to the Engineering Building, Central Laboratory and Office Building, Fabrication Laboratory, Check-Out Building, and Guidance and Control Laboratory. Estimated cost of the additions is \$7,800,000.

WALLOPS STATION, VA.

Launching Facilities

Facilities for launching the Scout vehicle and an auxiliary launch pad for Little Joe Project Mercury tests have been completed. Estimated costs are \$2,107,000.

DOVAP (Doppler Velocity and Position) and Ionosphere Facility

Construction of trailer parking aprons with power and antenna adjacent to liquid fuel storage has been completed. The DOVAP and Ionosphere Facility is employed in tracking sounding rockets and other vehicles launched at Wallops Station.

Communications

The causeway and bridge between the mainland and Wallops Island have been completed. Estimated cost is \$1,467,000. A tie cable has been installed for communication between the island and mainland, and terminal buildings have been erected at each end. An electrical wiring system connecting all island facilities has been designed. Estimated cost of cable, buildings, and duct system is \$400,000.

Other Projects

The Administration Building and the hangar have been enlarged to provide more floor space. The hangar can now be used for assembling the Scout launch vehicle. A rocket grenade sounding range and the Mercury capsule demonstration site have been completed. A new telemetry building was 85 percent

complete as the period ended. Design of an assembly shop for Scout and other launch vehicles has been started. Estimated cost of the shop, which will be erected on Wallops Island, is \$250,000.

ATLANTIC MISSILE RANGE, CAPE CANAVERAL, FLA.

Saturn Launch Facilities

Extensive preparations for launching Saturn, the 1.5-million-pound-thrust vehicle under NASA development, are being made at Cape Canaveral. The blockhouse near the Saturn launch pad was completed in July. This massive structure contains Saturn control and monitoring equipment. Its convex shell (composed of layers of concrete, steel, sand, and other materials) provides a 5-to 14-foot barrier to protect equipment and operating personnel against the rocket's blast. Estimated cost of the blockhouse is \$1,028,000.

About 40 percent of the 310-foot-high service structure (launch tower) for elevating and servicing the Saturn has been completed. Estimated cost is \$4,750,000. The design of an escape system to enable personnel to exit promptly from the service structure, if necessary, was 70 percent complete. Estimated cost is \$550,000.

About 90 percent of the construction of the launch pad (a steel and concrete platform from which the vehicle will be fired) and its related liquid-oxygen tanks and fuel lines has been completed.

In September, NASA began construction of the "umbilical" tower, which provides electrical circuits between the Saturn launch vehicle and the blockhouse while the vehicle is on the launch pad. An electrical cable connecting the tower to the vehicle is disconnected when the rocket ignites. Estimated cost of the tower is \$162,000.

Saturn Transportation Facilities

Dredging of the channel for the Saturn barge is 39 percent complete. Construction of the unloading dock and the roadway from the dock to the Saturn launch area is underway. Estimated costs are \$451,000.

Centaur Launch Facilities

Construction of facilities for Centaur launchings was about 90 percent complete. The facilities include a blockhouse, launch pads, service structure, fuel tanks and lines, and associated structures.

The Centaur (also called Atlas-Centaur) is one of several launch vehicles being developed by NASA. It is the first to use a high-energy upper stage fueled by liquid hydrogen and liquid oxygen. (See Chapter 7, Launch Vehicles and Launch Operations, pp. 74 .)

SECTION VI

NASA LIFE SCIENCES ACTIVITIES

Life Sciences Programs

ORGANIZATION PROGRESS

The Office of Life Science Programs, established as a fifth major division of NASA on March 1, 1960, has two broad objectives, to: 1) assure man's contribution to the success of space flight missions and to utilize his unique capabilities as the ultimate reservoir and integrator of scientific knowledge in space exploration; and 2) conduct biological investigations to determine the effects of remote environments on living organisms, including the search for extraterrestrial life. In the latter area, work is directed toward gaining information about the origin of life and its evolution in the universe -- one of the most important goals in the space effort.

NASA has established a grant and contract program to support the two principal goals of the Life Science Programs. Universities, non-profit research institutes, and industry are participating, and for some projects NASA funds are transferred to laboratories of other government agencies. The Office of Life Science Programs activities are organized in three general areas: 1) Flight Medicine and Biology; 2) Space Medical and Behavioral Sciences; and 3) Space Biology. Research grants and contracts in these fields, awarded during the report period, are listed in Appendix K.

Flight Medicine and Biology: Biotechnology

NASA activities in this field are centered on Space Biotechnology which is required to sustain human life during space flight and to insure man's effective performance in the control of missions. Means of providing an acceptable environment in the living quarters of spacecraft are being investigated. Physical and psychological effects of various stresses such as acceleration, tumbling, noise, and weightlessness are being studied. Integrated performance studies are being initiated to enable man to function effectively as a part of space man-machine systems, both manned and remotely operated. Other areas being investigated are crew sanitation, health physics, crew selection and training, support of advanced manned transport efforts, public health and ground crew safety.

Flight Medicine and Biology: Biomedical Flight Experiments

NASA is pursuing a program of biomedical experiments in extraterrestrial environments. In cooperative balloon flight experiments with the Department of the Air Force, four NASA biopacks contained mice for the study of cosmic ray effects. They were recovered in June 1960 after more than 10 hours of exposure above 130,000 feet at 52° magnetic north latitude. On September 19, a flight down the Pacific Missile Range (PMR) was made for study of the high energy radiation at approximately 1200 miles up. Termed Project NERV (Nuclear Emulsion Recovery Vehicle), the capsule of the experiment carried spores of the mold Neurospora to determine the effects of ionizing radiation. (For NERV details, see Chapter 4, Scientific Satellites and Sounding Rockets, pp. 37.)

NASA is developing future flight experiments for survival and performance studies, using animals, to support manned space flight programs. These experiments are being evaluated and integrated into the over-all program through the Space Science Steering Committee.

Space Medical and Behavioral Sciences

The purpose of this program is to furnish long-range support to manned space operations. Provision is thus made for the basic metabolic, radiological, physiological, and the broad aspects of psychological contributions to manned space flight. Research has been initiated in the area of physiological and psychological effects of angular velocity (spin), angular acceleration, coriolis accelerations, and tumbling, on healthy persons and on subjects with decreased, or loss of, function of the semicircular canals. Other studies are being conducted on the basic physiological mechanism which defends the human body against heat and cold, and to determine the extent and efficiency of energy transformations in the human body as well as isolated body constituents at the molecular level. The Office of Life Science Programs is also pursuing investigations to determine the mechanisms of injuries produced by exposure to vibration and to evaluate vibration as a biological stress.

Further endeavor in the area of space medical and behavioral sciences is the support of the Library of Congress for a compilation of a bibliography of biological, medical, and behavioral publications related to the exploration of space.

Space Biology

This is a long-range effort, dealing with the search for extraterrestrial life and the effects of simulated space environments on life forms, particularly at cellular and sub-cellular levels. An important goal is to develop a life detection device (vidicon microscope) that can be landed on the moon or another planet and transmit information back to earth. Other projects include: (1) development of techniques for decontaminating spacecraft to prevent interchange of earth's organic material with that of other planets, (2) development of various methods for detection and study of microorganisms on other planets, (3) use of various cellular systems and other life forms to investigate the biological effects of radiation in space, (4) study of living organisms (their metabolism and evolution) under conditions on other planets, (5) spectroscopic studies of planets and their environments to identify organic substances, (6) development of techniques to collect and identify microorganisms from the upper atmosphere and space, (7) study of primordial organic matter as it relates to the origin of life on the earth and on other planets, and (8) study of the effects of zero-gravity on biological systems, especially at the cellular level.

Three Life Sciences Committees Appointed

Three advisory committees have been appointed by the Administrator to assist in the development of NASA programs in the three areas discussed above. Members are listed in Appendices G, H, and I.

NASA-Department of Defense Coordination

NASA Office of Life Science biomedical programs were coordinated with those of the Department of Defense in three conferences held on April 26, June 22, and September 21, 1960. This coordinating group has been incorporated into the panel activities of the Aeronautics and Astronautics Coordinating Board. NASA has established informal liaison with the Division of Biological and Medical Sciences, National Science Foundation; the National Institutes of Health; the U.S. Public Health Service of the Department of Health, Education and Welfare; the Division of Biology and Medicine of the United States Atomic Energy Commission; and the Bureau of Aviation Medicine of the Federal Aviation Agency.

Foreign Scientists to Participate

The widespread human appeal and inherently peaceful intent of the life sciences programs in the exploration of space have made this area appropriate for inviting scientists of many nations to participate in the NASA programs. The invitation was made by Dr. Clark T. Randt, Director, Office of Life Science Programs, at the 11th meeting of the International Astronautical Federation in Stockholm, Sweden, August 17, 1960.

Biosciences Conferences

Spacecraft Decontamination Techniques -- On June 29, 1960, NASA held a bioscience conference in Washington, D.C., on "Problems and Techniques Associated with the Decontamination and Sterilization of Spacecraft." The conference was attended by delegates of laboratories and universities throughout the United States. A wide range of disciplines in the biological sciences, physical sciences, and engineering was represented. Emphasis was placed on the danger of contaminating terrestrial and extra-terrestrial bodies and on the means to prevent it. The current state of knowledge was discussed; areas needing additional effort or improvement were identified. Problems associated with decontamination of components were examined. A working group was established to resolve the joint problems of engineers and physical and biological scientists in developing decontamination and sterilization techniques.

Radiation Problems in Manned Space Flight -- On June 21, 1960, a working group on radiation problems in manned space flight convened in the Office of Life Science Programs. Dr. John R. Winckler, University of Minnesota, Dr. Cornelius A. Tobias, University of California, and Col. John E. Pickering, School of Aviation Medicine, USAF, were consultants. Representatives from NASA Headquarters, Goddard Space Flight Center, Langley Research Center, and Marshall Space Flight Center participated. Reviews were made of present knowledge of physical measurements of high energy radiation associated with solar disturbances, cosmic rays, and the earth's magnetic fields. Interpretation of these radiation measurements, in terms of their biological implications, the protection requirements and the means of obtaining further observations, were discussed. The intensity of radiation during solar disturbances was defined as one of the chief problem areas in prolonged manned space flight.

Biomedical Experiments in Extraterrestrial Environments -- Thirty of the nation's leading experimental biological, medical, and behavioral scientists conferred on June 20, 1960 under the

auspices of the Office of Life Science Programs. The purpose of this meeting was to establish goals, important areas of inquiry, and program priorities for life sciences flight experiments. The group recommended emphasis on the following: (1) detection and study of extraterrestrial life, (2) studies of the effects of space environments on living organisms, and (3) biological system studies, particularly those related to performance. The necessity of adequate control studies and experiments in earthbound laboratories was stressed.

SECTION VII

MANAGEMENT ACTIVITIES

Organizational Development

MARSHALL TRANSFER COMPLETED

Largest NASA Facility

Transfer of the Development Operations Division personnel and facilities from the Army Ballistic Missile Agency to form NASA's Marshall Space Flight Center was completed on July 1, 1960. Largest NASA center (5,500 employees), Marshall is the only one equipped to conduct a launch vehicle program from concept through testing.

President Dedicates Center

On September 8, the President dedicated the Center in honor of the late General George C. Marshall. Among those present at the ceremony were Mrs. Katherine Marshall, the general's widow; T. Keith Glennan, NASA Administrator; Wernher von Braun, director of the Center; and Governor John Patterson of Alabama.

Expansion of Functions

The Center had been engaged in developing the Saturn launch vehicle, of which NASA has been technical director since November 1959. Effective July 1, NASA assigned Marshall field responsibility for development of the Centaur launch vehicle and the F-1 single-chamber, 1.5-million-pound thrust engine; for adaptation of the Air Force Thor-Agena B and Atlas-Agena B boosters to NASA missions; for Redstone firings of the Mercury capsule; for studies leading to advanced rocket engines and propulsion mechanisms; and, through the Launch Operations Directorate (see below), for NASA launches at the Atlantic Missile Range, Cape Canaveral, Fla., and the Pacific Missile Range, Point Arguello, Calif.

NEW LAUNCH ORGANIZATION ACTIVATED

Concurrent with the transfer of the Marshall Space Flight Center, NASA established a Launch Operations Directorate to coordinate all the agency's launchings at

Cape Canaveral, Fla., and Point Arguello, Calif. The Launch Operations Directorate also assumed the obligation to assist the Army with its Jupiter, Redstone, and Pershing rocket programs. The directorate reports to the Marshall Space Flight Center. Its headquarters is at Cape Canaveral, Fla.

OFFICE OF TECHNICAL INFORMATION AND EDUCATIONAL PROGRAMS ESTABLISHED

NASA established the Office of Technical Information and Educational Programs on May 30, 1960, to increase emphasis on its fulfillment of responsibilities in these areas. It consolidated the following functions within the office: youth program -- see Chapter 18, Personnel, p. 204 -- and technical information (formerly with the Office of Business Administration), translations (formerly with Office of Advanced Research Programs), and history, exhibits, motion pictures, and reports (formerly with Office of Public Information). The new office reports to the Office of the Associate Administrator.

ADMINISTRATION OF RESEARCH GRANTS AND CONTRACTS REORGANIZED

On May 16, 1960, NASA reorganized its research grants and contracts program to improve administration. The principal modifications are:

- 1) Transfer of the Office of Research Grants and Contracts from the Office of Advanced Research Programs to the Office of Business Administration.
- 2) Assignment of scientists to the staff of the Office of Research Grants and Contracts. Its staff had been exclusively composed of contract specialists.
- 3) Arranging for field installations to administer and technically monitor certain research grants and contracts pertaining to studies in which they had a major interest. The Headquarters Office of Research Grants and Contracts had performed these functions. The office retains responsibility for: 1) over-all supervision and coordination of the program; 2) developing policies and procedures, 3) evaluating proposals, and 4) making awards.

NUCLEAR PROPULSION COORDINATION OFFICE ESTABLISHED

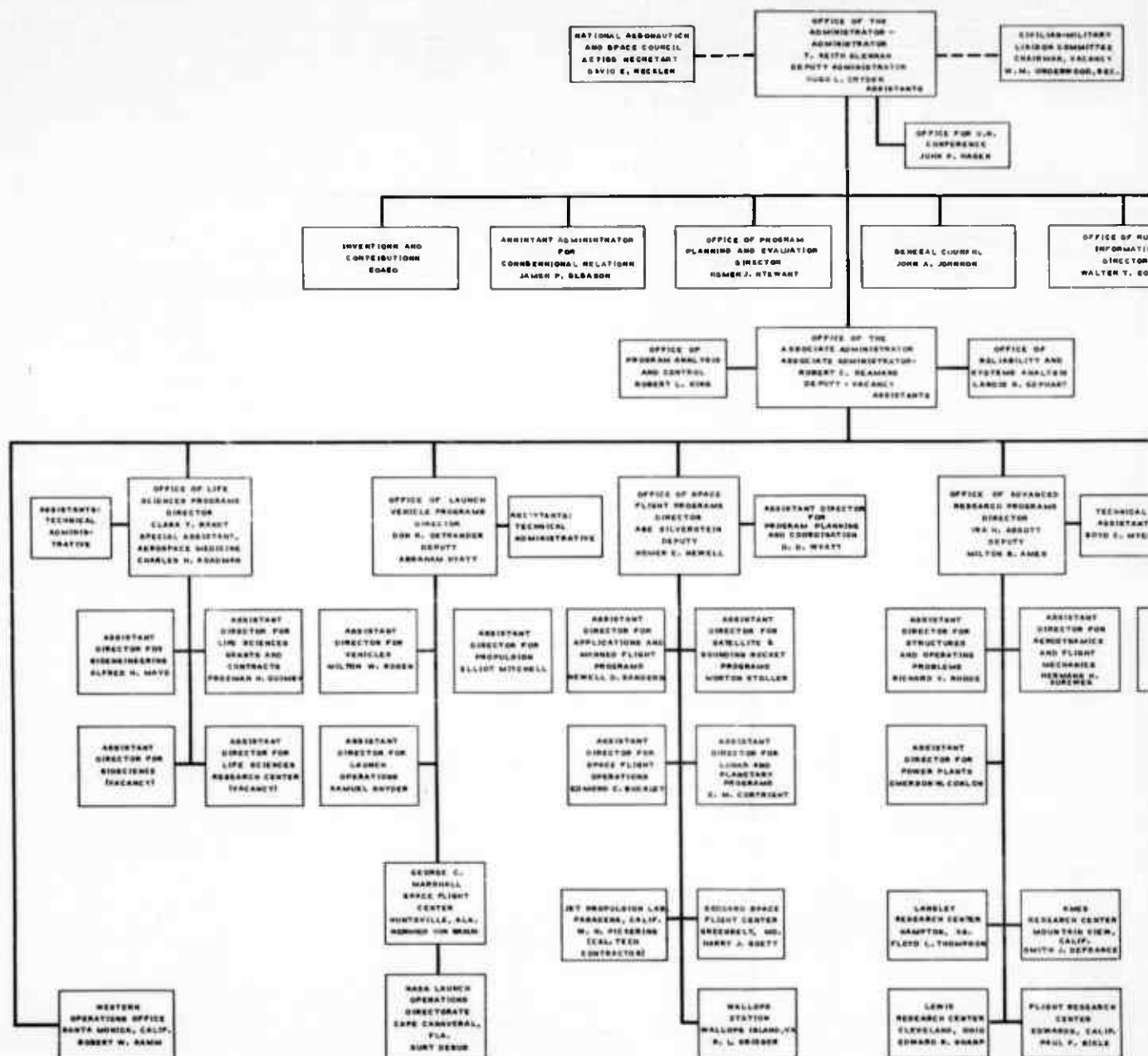
On August 29, 1960, NASA and the Atomic Energy Commission (AEC) established a joint Nuclear Propulsion Office to coordinate and consolidate nuclear propulsion activities. The office is located at AEC Headquarters, Germantown, Md. (See Chapter 8, Propulsion and Nuclear Energy Applications for Space, p. 105)

NASA AND DOD ORGANIZE COORDINATING BOARD

On September 13, 1960, NASA and the Department of Defense (DOD) announced formation of an Aeronautics and Astronautics Coordinating Board. The Board will: 1) review planning and work of the two agencies to prevent duplication, 2) coordinate activities of common interest, 3) facilitate exchange of information, and 4) identify problems requiring solution by either NASA or DOD. The Board's first meeting since the announcement was on September 16 at the Pentagon. The Board will meet at least every two months at the call of its co-chairmen. Members of the Board are officials who are managing military and civilian programs in aeronautics and space. In addition to two co-chairmen, the Board includes chairmen of panels to coordinate specific phases of aeronautics and space programs, two members at large, and two secretaries. NASA and the Department of Defense are represented equally. Board members and vice-chairmen of panels are listed in Appendix C.

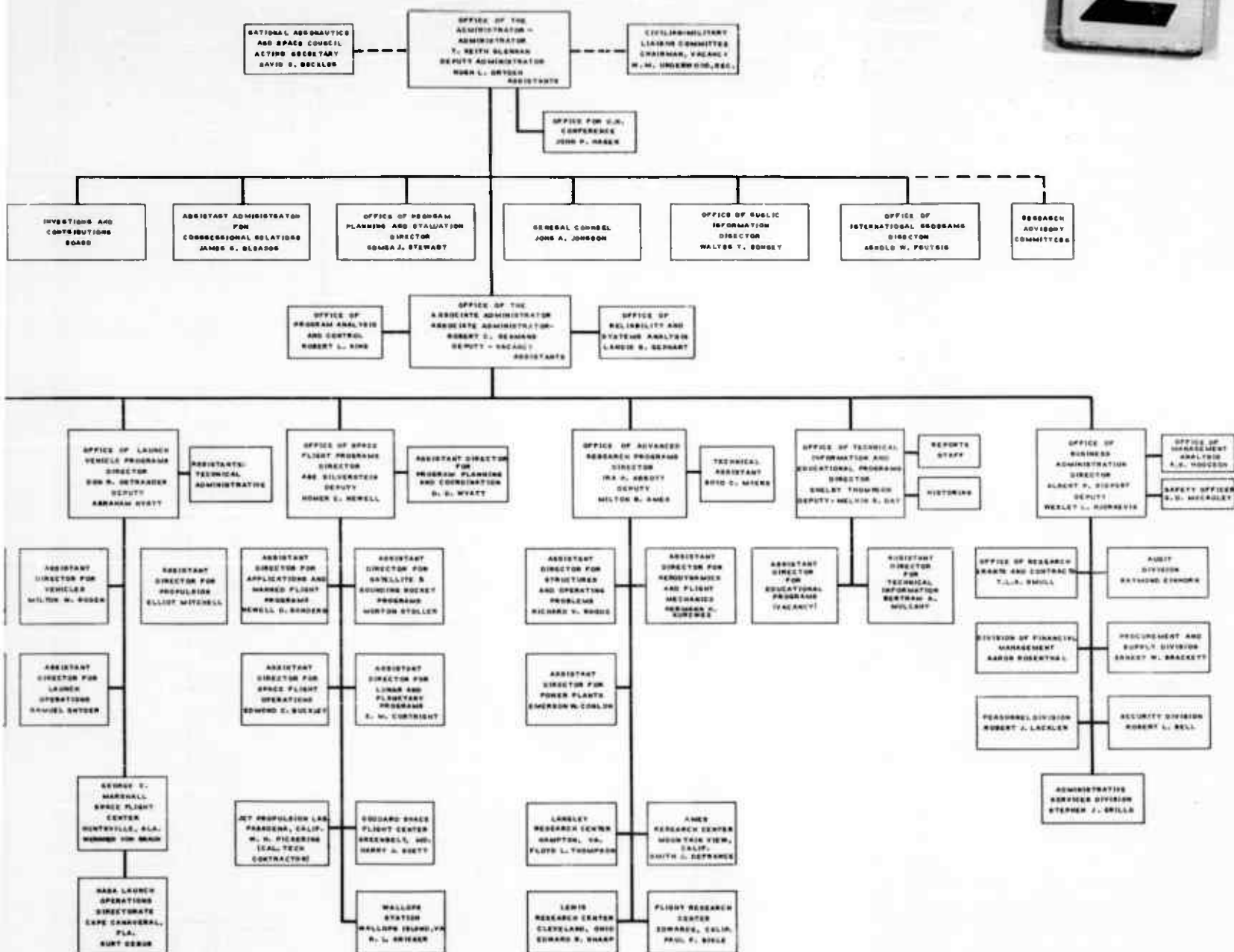
ORGANIZATIONAL CHART

The chart on page 194 illustrates NASA organizational structure as of September 30, 1960. NASA's First, Second, and Third Semiannual Reports to Congress describe functions of units established earlier.



ORGANIZATIONAL CHART NATIONAL AERONAUTICS AND SPACE ADMINISTRATION SEPTEMBER 30, 1960

2



Procurement, Contracts, and Grants

BULK OF NASA BUDGET SPENT WITH INDUSTRY

NASA's procurement during the six months ending September 30, 1960, totaled, on an obligation basis, approximately \$240 million. These obligations resulted from a total of about 31,000 procurement actions by NASA Headquarters and its seven field procurement offices.

In accordance with NASA's mission, most of its purchases and contracts (\$192 million or 80 percent) were for research and development. Construction awards amounted to \$26 million (11 percent) of the total. About \$19 million (8 percent) comprised purchases and contracts for supply items. The remaining \$3 million (1 percent) was not categorized by purpose,

Procurement Placement

Of the \$240 million obligated during the period, \$151 million (63 percent) was placed directly with business firms. About \$9 million (4 percent) was awarded to educational and other nonprofit institutions and \$80 million (33 percent) was placed with, or through, other Government agencies.

Method of Placement - Awards to Business

Approximately \$18 million (12 percent) of the purchases and contracts awarded to business firms was placed through formal advertising for competitive bid. About \$121 million (80 percent) was placed through negotiation. Approximately \$12 million (8 percent), constituting amendments, purchases not exceeding \$2,500, and purchases under General Services Administration contracts, was not categorized as to whether advertised or negotiated.

The extent of awards to business through negotiation reflects the fact that NASA's activities are predominantly in research and development. Awards for R&D contracts are usually negotiated because definitive specifications can seldom be developed.

As shown in Table 2, below, 77 percent of the dollar awards to business was for research and development. Virtually all of these awards were negotiated. However, with respect to construction awards, which accounted for 15 percent of the total to business, 51 percent of the dollar value was advertised and 49 percent negotiated. Awards for supply items amounted to eight percent of the total awards to business. Of these, 35 percent was advertised and 65 percent negotiated. Thus, of the total awards for construction and supply, 46 percent of the dollar value was placed through advertising and 54 percent through negotiation.

TABLE 2

Method of Placement by Program Purpose

Direct Awards to Business

April 1, 1960 Through September 30, 1960

Purpose	Value		Percent Advertised	Percent Negotiated
	Millions	Percent of Total		
Total	<u>\$139.3</u>	<u>100</u>	<u>13</u>	<u>87</u>
Research & Development	107.6	77	3	97
Construction	21.3	15	51	49
Supply	10.4	8	35	65

The extent of competition in NASA procurement cannot be measured solely by the amount placed through formal advertising. Even in negotiation, NASA policy is to encourage widest possible competition by requesting all qualified firms to submit detailed proposals and cost data.

Procurement From or Through Other Government Agencies

To avoid duplication of effort and achieve the most economical and efficient utilization of Government resources, NASA placed about \$80 million (33 percent) through or with other Government agencies, mainly the Department of Defense.

NASA buys through the Department of Defense items for which the military departments can most economically contract. For example, NASA has allocated funds to the Air Force to procure Agena B rockets for use as upper stages of Atlas-Agena and Thor-Agena launch vehicles. The Air Force has employed Agena rockets in its Discoverer and MIDAS satellite programs. NASA has also transferred funds to the Air Force to construct test stands at Edwards AFB, Calif., for the F-1 project, development of a 1.5-million-pound thrust rocket engine.

About \$70 million (88 percent) of funds placed with or through other agencies was for research and development. Approximately \$10 million (12 percent) was for construction and supply, in almost equal shares.

MAJOR CONTRACT AWARDS

Among the major research and development contracts awarded by NASA were the following:

1) Douglas Aircraft Co., Santa Monica, Calif., for developing and producing ten S-4 second stages for the initial (C-1) Saturn launch vehicles. Estimated cost: \$70 million.

2) Rocketdyne Division, North American Aviation, Inc., Canoga Park, Calif., for development of a 200,000-pound thrust single-chamber rocket engine (designated J-2), fueled by liquid hydrogen and liquid oxygen (LOX). Estimated cost: \$45 million over a three-year period.

3) Aerojet-General Corp., Azusa, Calif., to construct the SNAP-8 (System for Nuclear Auxiliary Power) electric generation system. Estimated cost: \$8 million.

4) The TAPCO Group, Thompson-Ramo-Wooldridge, Inc., Cleveland, Ohio, for development of Sunflower-I, a 3-kw solar auxiliary power system for spacecraft. Estimated cost: \$4 million.

5) Hughes Aircraft Co., Culver City, Calif., to build an experimental ion engine. Estimated cost: \$500,000.

Details of the work covered by these contracts appear in Chapter 8, Propulsion and Nuclear Energy Applications for Space, pp. Appendix L lists contract awards and amendments of \$100,000 and over.

RESEARCH GRANTS AND CONTRACTS

Eighty-Three Awards Made

Eighty-three research grants and contracts totalling \$7,436,218 were awarded, bringing to 216 the number in effect. Educational and other non-profit organizations received 65 awards aggregating \$6,443,207. Forty of the awards were for basic research in aeronautics and space flight and 43 for support of specific space flight projects.

Research grants, contracts, and transfers are listed in Appendix K. Work under the research grants and contracts program is either supporting (for instance, studies of problems in manned space flight) or fundamental (for example, theoretical investigations in physical sciences).

PROCUREMENT MANAGEMENT

Revised Procedure for Source Evaluation and Selection

A revised procedure for major systems procurement was developed during the reporting period and will be put into effect in January 1961. The three main elements of the procedure are the preparation of a procurement plans, the use of a source evaluation board, and the development of a reliability program.

Procurement Plan -- The contracting officer outlines in detail the method by which he expects to award the contract. The procurement plans usually provides for use of a source evaluation board.

Source Evaluation Board -- A NASA source evaluation board analyzes proposals from prospective contractors, based on specific criteria established before the proposals are opened. The source evaluation board is composed of NASA scientists and engineers familiar with the technical details of the proposed procurement, and one or more representatives of the NASA business management staff. The board may be convened at NASA headquarters or at the field installation placing the contract. Findings of the board are reported to the NASA Administrator, if at headquarters, or to research or space flight center directors, if in the field. The Administrator or the center director makes the final selection of the company with whom the contract will be negotiated.

Reliability Program -- NASA's requests for proposals from industry specify a system reliability goal and require

competing contractors to show in their proposals how it will be accomplished. NASA may employ a reliability contractor as consultant during proposal review and as monitor during equipment development.

Preparation of Procurement Regulations

During the six-month period, NASA issued regulations on: foreign purchases, architect-engineer services, labor, contract cost principles, procurement action reports, and negotiation, award, and administration of research grants. The following regulations were being drawn up and were near completion: contract clauses and forms, numbering and distribution of contracts and grants, inspection and acceptance, and patents data and copyrights. Procurement personnel were drafting regulations on small business, Government property, communications services, and Federal, state, and local taxes. NASA procurement regulations are published as developed in Title 41 of the Code of Federal Regulations.

SMALL BUSINESS

Summary of Awards

NASA awarded \$24 million in purchases and contracts to small business, about 16 percent of the money spent with industry. The \$24 million was obligated through 19,000 procurement actions, constituting about 65 percent of contracts and amendments to contracts placed with business firms.

From a dollar standpoint, \$12 million (50 percent) of the awards was for research and development; \$6 million (26 percent) for construction; \$4 million (16 percent) for supply; and \$2 million (8 percent) was not categorized because it represented amendments or actions not exceeding \$2500.

Not included above are thousands of small business subcontracts with NASA prime contractors.

Program Management

To assure small business an equitable opportunity to compete for NASA contracts and subcontracts, NASA and the Small Business Administration have jointly been developing

procedures for executing small business policies set forth in the National Aeronautics and Space Act and the Small Business Act. During a series of meetings at NASA field centers, representatives of the two agencies drafted comprehensive small business procedures for NASA procurement programs. The procedures cover such areas as screening proposed procurement actions for small business participation, small business subcontracting programs under NASA contracts, maintenance of records, and consolidation of reports covering small business participation in NASA procurement. Final procedures will be issued soon.

NASA has been taking part in business opportunity conferences and trade exhibitions throughout the United States. NASA participation has been in the form of displays, distribution of literature describing NASA organization and purchasing procedures and attendance by small business specialists for "on the spot" response to inquiries made by visitors to the exhibitions. A revised edition of "Selling to NASA" was issued in July 1960 and widely distributed to business concerns. The purpose of this booklet is to provide guidance to firms seeking business opportunities in the aeronautics and space programs of NASA.

NASA BRIEFS INDUSTRY ON LONG-RANGE PLANS

NASA began a series of classified briefings for industry and other organizations on the agency's plans and its requirements for new equipment. The first briefing, held July 28 - 29 in Washington, D.C., outlined the NASA Long Range Plan and policies and procedures on procurement and patents. The briefing was attended by about 1,300 representatives of industry, educational institutions, research foundations, and Government agencies working on aeronautics and space.

Two conferences on field center activities followed. The Goddard Space Flight Center conference was held in Washington, D.C., on August 30 before an audience of 1,042 representatives of industry, private research groups, and Government. About 400 attended the conference at Marshall Space Flight Center, Huntsville, Ala., on September 27 - 28. At each session, NASA officials and scientists outlined technical programs and procurement requirements of the center, with emphasis on major procurement during the next two to three years. NASA published and distributed to the conferees unclassified portions of conference proceedings.

A third conference is scheduled at the Jet Propulsion Laboratory, Pasadena, Calif., for October 26.

Personnel

THE NASA STAFF

NASA employment rose from 9,755 to 15,603 during the six-month period -- reflecting, for the most part, the transfer of Development Operations Division to NASA from the Army Ballistic Missile Agency. This group was renamed Marshall Space Flight Center. Contributing to the increase were the requirements imposed by intensified activities in all areas of the Nation's civilian space program. Table 3 shows distribution of NASA personnel among organizational units on March 31, 1960, and September 30, 1960.

Personnel strength is expected to climb to 16,373 by June 30, 1961. Most of the additional employees will be assigned to Marshall, and to Goddard Space Flight Center which is being built at Greenbelt, Md.

Of NASA's 15,603 employees on September 30, 1960, a total of 3,958 are research scientists, space scientists, and personnel in related supervisory and management positions; 1,261 are engineers, mathematicians, and other professionals whose work supports the preceding group; 1,675 are scientific and engineering assistants and technicians such as draftsmen, designers, computer specialists, illustrators, and photographers; 720 are in management fields requiring a broad and comprehensive understanding of the science and technology of aeronautics and space, such as financial management, procurement, personnel, technical information, and legal counsel; 2,175 are in clerical and administrative positions not directly related to scientific programs; and 5,814 are in skilled trades and crafts.

Included in the NASA staff are 82 foreign scientists and 104 military personnel on loan from the Armed Services.

The staffing figures above do not include 2,783 employees of the Jet Propulsion Laboratory, Pasadena, Calif., which is operated for NASA under contract by the California Institute of Technology.

TABLE 3
Distribution of NASA Personnel*

<u>Organizational Unit</u>	<u>March 31, 1960</u>	<u>September 30, 1960</u>
Langley Research Center	3,197	3,220
Ames Research Center	1,426	1,433
Lewis Research Center	2,737	2,726
Flight Research Center	373	414
Goddard Space Flight Center	1,193	1,606
Marshall Space Flight Center	26	5,238**
Wallops Station	229	297
Atlantic Missile Range		
Operations Office	12***	--
Western Operations Office	32	41
 Total Field	 9,225	 14,975
Headquarters	530	628
 TOTAL	 9,755	 15,603

* Locations of the organizational units are shown on the map, page .

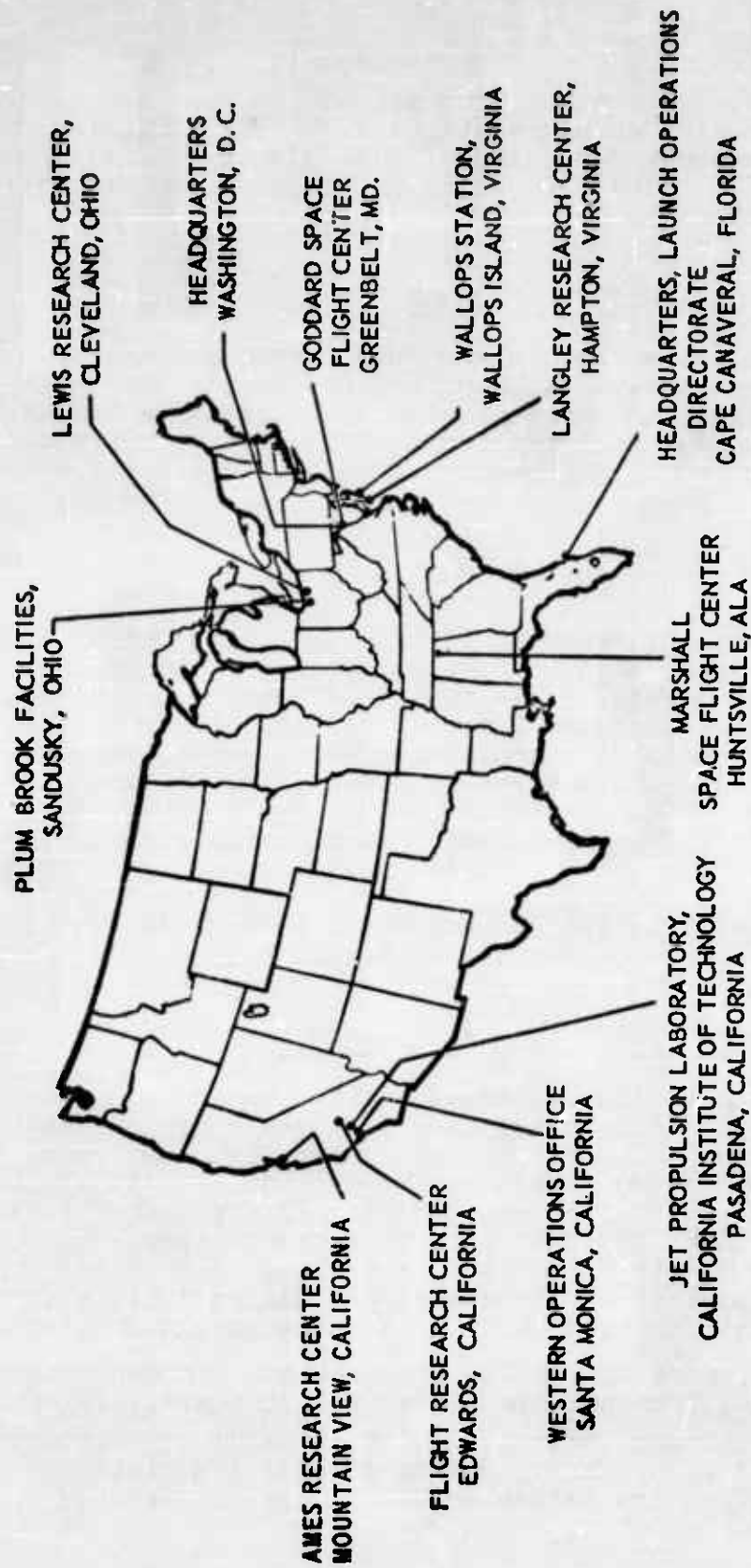
** Includes employees assigned to Launch Operations Directorate.

*** Merged with Launch Operations Directorate on July 1, 1960.

RECRUITING SCIENTIFIC PERSONNEL

During fiscal year 1960, NASA representatives visited 189 colleges and universities and interviewed 2,904 graduating science students. In addition, the agency employed other recruitment aids such as classified advertisements in professional and technical journals, follow-up of referrals made by NASA employees, and recruiting at meetings of professional and technical societies.

As a result, more than 2,000 applications for employment have been received from college students. Of these, 429 applicants were qualified for specific vacancies, and 201 accepted employment.



Locations of NASA Installations.

In addition, 120 applications already in the labor force were employed, making an aggregate total of 321 scientists hired. This was about one-third of NASA hirings in all fields which totaled 997. (The figures do not include the Marshall Space Flight Center.)

YOUTH PROGRAM

The National Science Teachers Association and the National Aviation Educational Council distributes NASA material on aeronautics and space to high school science teachers throughout the U. S. NASA replies individually to numerous career inquiries from young people, inclosing descriptive publications.

DR. DRYDEN HONORED

In September, the Franklin Institute, Philadelphia, Pa., named Hugh L. Dryden, NASA Deputy Administrator, to receive its Elliott Cresson Medal. The institute honored Dr. Dryden for "his many scientific and practical contributions to the theory and application of aerodynamics which greatly advanced the art of wind tunnel and aircraft design, and for his guidance of and personal contributions to the design and development of the world's first automatic radar homing guided missile."

Dr. Dryden will be awarded the medal during the annual Medal Day ceremonies, October 19, at Franklin Institute.

EXECUTIVE PERSONNEL CHANGES

John F. Victory, Special Assistant to the Administrator, retired on July 31, 1960, after nearly 52 years of continuous Government service. Dr Victory was the first employee of the National Advisory Committee for Aeronautics (NACA) in 1915 and was instrumental in establishing NACA research facilities. He made many important contributions to aeronautics, among which were helping to formulate national and international air regulations. His awards and honors include a Presidential Medal for Merit in 1947 and the Wright Brothers Memorial Trophy in 1958.

Robert C. Seamans, Jr., former chief engineer of the Missile Electronics and Controls Division, Radio Corporation of America, Burlington, Mass., was named NASA Associate Administrator, effective September 1. He serves directly

under the Administrator and Deputy Administrator, succeeding Richard F. Horner who resigned to become senior vice president (technical) of Northrop, Inc., Beverly Hills, Calif.

On September 1, Robert G. Nunn, Jr., was appointed Special Assistant to the NASA Administrator. Mr. Nunn was formerly Assistant General Counsel of NASA. His new duties involve policy related to the utilization of non-military communications satellite systems.

Shelby Thompson, former Deputy Director, Division of Information Services, Atomic Energy Commission (AEC), was appointed Director of the Office of Technical Information and Educational Programs, established in Headquarters on May 30. Melvin S. Day was named Deputy Director of the new office. Mr. Day had been Director of Technical Information Services at AEC.

On May 23, Floyd Thompson, former Deputy Director, Langley Research Center, Hampton, Va., was appointed Director of that installation. He succeeded Henry J. Reid who became the center's senior staff associate.

Effective July 1, the Marshall Space Flight Center, Huntsville, Ala., transfer to NASA was accomplished, Wernher von Braun is Director; Eberhard F. M. Rees is Deputy Director for Research and Development; and Delmar M. Morris is Deputy Director for Administration. Kurt Debus, former chief of the Missile Firing Laboratory, Army Ballistic Missile Agency, Cape Canaveral, Fla., became Director of the Launch Operations Directorate, headquartered at Cape Canaveral.

On August 29, NASA and the Atomic Energy Commission jointly established an AEC-NASA Nuclear Propulsion Office staffed with personnel from both agencies. Harry Finger, former Chief, Nuclear Propulsion Programs, NASA, was designated as Manager of the office. The office is responsible for planning and directing both AEC and NASA programs relating to nuclear propulsion.

RESEARCH CENTER WINS SAFETY AWARD

In April, the National Safety Council announced that NASA's Flight Research Center, Edwards, Calif., had won first place in the Research and Development Group, Aeronautical Industries Safety Contest, for calendar year 1959. Twelve groups from Government and industry were entered in the contest.

Council statistics showed there were only two disabling injuries at the Flight Research Center in 1958, none in 1959, and none in 1960 to the date of the award. As of September 30, 1960, Edwards personnel had worked 1,647,281 man hours without disabling injury.

Financial Management

Financial management activity during the reporting period centered upon three different budgetary programs: 1) execution of the final quarter in Fiscal Year 1960, 2) operational programming of the entire Fiscal Year 1961 budget along with actual execution of the first quarter, and 3) preparation, review, and internal approval of the funds estimated for Fiscal Year 1962. The following tables depict the financial progress and status of the agency during and at the close of the reporting period:

Table 4, Financial Report, June 30, 1960

This table depicts the end-of-the-fiscal-year condition of NASA funds for Salaries and Expenses, Research and Development, and Construction and Equipment.

TABLE 4

NASA Fiscal Year 1960 Program Effort

	<u>Total Obligations</u>	<u>Pending Commitments</u>	<u>Total Expenditures</u>
Salaries & Expenses.....	\$ 89,374,541	\$ ---	\$ 82,096,853
Research & Development			
Support of NASA Plant.....	23,163,233	3,960,000	14,734,711
Research Grants & Contracts.....	4,740,834	740,000	2,531,536
Support of JPL Plant.....	---	---	3,748,675
Sounding Rockets.....	6,801,187	3,050,000	5,714,204
Scientific Satellites.....	15,523,816	3,650,000	16,192,924
Lunar & Planetary Exploration.....	37,854,040	1,070,000	43,357,878
Vanguard.....	319,384	100,000	7,416,870
Meteorology.....	5,417,993	2,730,000	2,741,376
Communications.....	2,214,828	690,000	3,682,907
Manned Space Flight.....	88,299,056	5,330,000	66,568,050
Vehicle Systems Technology.....	4,663,000	---	2,308,571
Solid Rockets.....	2,616,081	1,290,000	516,622
Liquid Rockets.....	27,186,646	3,760,000	25,523,614
Nuclear Systems Technology.....	3,954,838	4,470,000	3,396,008
Space Power Technology.....	1,087,309	2,470,000	23,084
Scout.....	2,925,468	800,000	4,343,281
Delta.....	11,346,150	890,000	12,545,290
Vega.....	3,572,615	570,000	11,241,074
Centaur.....	36,466,351	20,000	17,425,520
Saturn.....	9,394,214	50,000	2,125
Vehicle Procurement.....	6,250,000	820,000	68,486
Supporting Activities.....	14,104,930	1,840,000	9,662,936
Total Research & Development	\$307,901,973	\$ 38,300,000	\$253,745,742
Construction & Equipment.....	\$ 89,670,495	---	\$ 54,368,657

Table 5, Fiscal Year 1961 Program

This table depicts the agency program planned for the funds approved by the Congress in Public Law 86-626, signed July 13, 1960. The various program totals within the Research and Development area represent the program activity in terms of level of effort originally estimated as of the time of submission to the Congress. During the course of the fiscal year, reprogrammings are made as necessary to carry out new or modified program responsibilities and requirements.

TABLE 5

NASA Budget Estimate, Fiscal Year 1961

<u>Appropriations</u>	<u>1961 Estimated</u>
Salaries & Expenses.....	\$170,760,000
Research & Development	
Support of NASA Plant.....	\$ 51,345,000
Research Grants & Contracts.....	10,000,000
Sounding Rockets.....	8,000,000
Scientific Satellites.....	41,700,000
Lunar & Planetary Exploration.....	45,000,000
Meteorology.....	20,700,000
Communications.....	5,600,000
Manned Space Flight.....	107,750,000
Tracking & Data Acquisition.....	32,550,000
Vehicle Systems Technology.....	21,200,000
Solid Rockets.....	2,800,000
Liquid Rockets.....	63,000,000
Nuclear Systems Technology.....	10,000,000
Space Power Technology.....	8,000,000
Delta.....	12,500,000
Centaur.....	47,000,000
Saturn.....	134,308,000
Total Research & Development.....	\$621,453,000
Construction & equipment.....	\$122,787,000
Total.....	<u>\$915,000,000</u>

Table 6, Financial Status as of September 30, 1960

This table depicts the actual status of appropriations for FY 1961 as of the last day of the reporting period. It shows the total amounts of funds obligated, committed, and expended.

TABLE 6

FY 1961 Financial Status as of September 30, 1960

<u>Appropriation</u>	<u>Total Obligations</u>	<u>Pending Commitments</u>	<u>Total Expenditures</u>
Salaries and Expenses.....	\$ 39,150,549	\$ ---	\$ 29,247,268
Research and Development			
Support of NASA Plant.....	11,644,000	9,526,000	
Grants and Contracts.....	665,000	---	
Sounding Rockets.....	360,000	3,497,000	
Scientific Satellites.....	1,568,000	4,406,000	
Lunar and Planetary Exploration.....	510,000	6,514,000	
Meteorology.....	918,000	5,840,000	
Communications.....	543,000	206,000	
Manned Space Flight.....	13,888,000	18,999,000	
Tracking and Data Acquisition.....	3,327,000	7,946,000	
Launch Operations Development.....	---	---	
Vehicle Systems Technology.....	(68,000)	2,302,000	
Solid Rockete.....	887,000	410,000	
Liquid Rockets.....	5,048,000	23,919,000	
Nuclear Systems Technology.....	1,064,000	6,165,000	
Electric Propulsion Technology.....	15,000	269,000	
Space Power Technology.....	315,000	2,655,000	
Spacecraft Technology.....	---	---	
Scout.....	1,086,000	515,000	
Delta.....	5,000	7,743,000	
Centaur.....	1,437,000	21,134,000	
Saturn.....	22,296,000	22,474,000	
Vehicle Procurement.....	13,392,000	1,490,000	
Propellant Procurement.....	242,000	1,250,000	
Life Sciences.....	469,000	---	
Other			
Vega.....	---	(230,000)	
Total, Research and Development	\$ 79,611,000	\$147,030,000	\$ 72,044,383
Construction and Equipment.....	\$ 12,957,344	---	\$ 24,560,997

Other Activities

SCOPE OF CHAPTER

This chapter reports significant recent developments in: 1) NASA patent administration, 2) actions of the agency's Inventions and Contributions Board, 3) long-range studies and planning, and 4) information and education programs.

NASA PATENT PROGRAM

This program carries out NASA's responsibilities under the National Aeronautics and Space Act of 1958, other statutes, and Executive Orders relating to: 1) patents for inventions made in performance under NASA contract and 2) inventions by NASA employees. Legal assistance on patent matters is provided by the Office of Assistant General Counsel for Patent Matters at NASA Headquarters and by patent counsel at Langley and Lewis Research Centers, Marshall and Goddard Space Flight Centers, and the Western Operations Office.

NASA patent counsel serves not only this agency but also, upon request, individuals and organizations such as patent attorneys, contractors, companies interested in NASA contracts, and NASA employees.

Reporting of Inventions by NASA Contractors

NASA contractors must promptly furnish the Administrator written reports of inventions made under NASA contract. During the past six months, contractors reported 33 inventions. NASA acquired title to 19 of these under Section 305(a) of the National Aeronautics and Space Act and granted waivers of rights to two inventions under Section 305(f) of the Act. At the end of the report period, NASA was considering nine determinations of title for contractors' inventions and 10 petitions for waiver of rights.

Protection of NASA Inventions

NASA prepares patent applications for inventions, disclosed by employees or contractors, which appear to have significant utility in the U.S. space program. During the period, it received 75 invention disclosures from NASA personnel and 19 invention disclosures from contractors on which the contractors did not intend to file patent applications. NASA authorized patent applications for 29 inventions, prepared 35 patent applications, and issued nine patents. Of the nine patents issued, the Government acquired four assignments of title and five licenses to use the inventions for governmental purposes.

U.S. Settles Goddard Patent Claim

Guggenheim Foundation Receives \$1 Million -- NASA and the Department of Defense announced in August that they had agreed to pay \$1 million to the Daniel and Florence Guggenheim Foundation for use of the patented rocket inventions of the late Dr. Robert H. Goddard, U.S. rocketry pioneer. The foundation had supported Dr. Goddard's research in rocket propulsion systems during the 1930's. Mrs. Goddard, the scientist's widow, transferred her rights in the award to the foundation for a consideration, the amount of which was not disclosed.

Armed Services and NASA To Share Payment -- Of the \$1 million, the Air Force will pay \$765,000, the Army \$125,000, NASA \$100,000, and the Navy \$10,000. The settlement licenses the Government to use more than 200 patents applicable to rockets, guided missiles, and launch vehicles.

Settlement Covers Two Patents -- To speed settlement of the case, the Government acknowledged infringements on two broad patents which Dr. Goddard applied for in 1940 and 1941, and received in 1946. These covered a means for a sustained flow of power by liquid propellant rockets, instead of power by a single explosion. Dr. Goddard's designs for control and pumping instruments are utilized in the Redstone, Atlas, Jupiter, and Thor rockets and in NASA launch vehicles incorporating these rockets (such as Delta, Centaur, and Saturn).

Other Patent Infringement Claims

During the report period, NASA received two new administrative claims for patent infringement. It was investigating three as the period ended.

Review of Patent Applications

Section 305(c) of the National Aeronautics and Space Act provides that the Administrator review patent applications having significant utility in aeronautical and space activities. In accordance with this provision, the U.S. Commissioner of Patents transmitted to NASA 42 patent applications during the report period. NASA determined that none had been made under NASA contracts.

INVENTIONS AND CONTRIBUTIONS

Purpose and Authority

NASA's Inventions and Contributions Board (see Appendix F for membership) operates under authority of, and in accordance with, Sections 305(f) and 306 of the National Aeronautics and Space Act of 1958. The board considers petitions from NASA contractors for waiver of U.S. patent rights to inventions during work under a NASA contract and evaluates for monetary awards scientific and technical contributions by NASA employees, and other persons, and organizations.

Third Waiver Petition Granted

On May 5, 1960, the Board recommended to the NASA Administrator that the Government waive rights to an invention made by McDonnell Aircraft Corp., St. Louis, Mo., under NASA contract. Previously, NASA had granted waivers to the Pratt & Whitney Division, United Aircraft Corp., East Hartford, Conn., (August 3, 1959), and the Bell Aircraft Corp., Buffalo, N.Y. (March 16, 1960).

Contributions Awards

During the report period, the Inventions and Contributions Board received 778 scientific and technical contributions and determined that 680 did not warrant monetary awards under the National Aeronautics and Space Act. A hearing was held on September 21 on the application of one contributor as provided for in Section 306(a) of the Act. Of cases pending at the end of the report period, several were recognized as meriting awards, but terms and conditions to be recommended to the Administrator had not been determined.

LONG RANGE STUDIES

During the report period, work went forward under contracts awarded by NASA's Committee on Long Range Studies to four private research organizations to study the wide-ranging socio-economic and political implications of space technology and activities. The contracts total about \$372,000. The committee was established by NASA pursuant to subsection (4) of section 102(c) of the National Aeronautics and Space Act of 1958 to consider the economic, social, political, international, and legal implications of space research and exploration.

The four contracts are as follows:

1) A \$223,000 contract with the Rand Corp., Santa Monica, Calif., to review economic and international implications of space technology. The economic studies deal specifically with the costs of, and benefits from, such practical space technology applications as communications and meteorological satellites. The international study will analyze the problems of cooperation, control, and administration of peaceful space activities.

2) A \$96,000 Brookings Institution, Washington, D.C., survey of the social, economic, political, legal, and international implications of space exploration for the purpose of preparing a suggested long-range program of research and study to be considered by NASA in planning its future activities in this area.

3) A \$48,000 United Research, Inc., Cambridge, Mass., study of the relations of scientific and professional groups to policy formation and public information within NASA.

4) An American Bar Foundation, Chicago, Ill., study on outer space law in the amount of \$5,000 involving review and analysis of all the literature and the proposals for the control and administration of space activities.

As a continuing function, the Committee on Long Range Studies confers with representatives of universities and private research groups interested in fostering and awareness on the part of the public in the social implications of space activities for peaceful and scientific purposes.

INFORMATION AND EDUCATION

Technical Information

International Exchange Program -- NASA is fostering world interchange of scientific and technical aeronautics and space data. Expanding its technical information exchange programs, the agency is distributing its publications to depositories in 30 nations, including all NATO members but one, with which discussions were in progress as the report period ended.

Technical Publications Release -- The agency released 351 new technical publications. Of these, it distributed generally 250 unclassified publications and furnished 101 classified publications to selected Government agencies and organizations participating in U.S. aeronautical and space activities. NASA also filled 14,970 separate requests for documents or other items of technical information.

Domestic Information Exchange and Coordination -- A NASA representative serves on a new Government interagency committee established to correlate activities related to space-oriented technical information. Members of NASA also participate in the Science Information Exchange (SIE), which furnishes information on current projects in the biological and physical sciences. SIE, an expansion of the former Biological Science Information Exchange, is administered by the Smithsonian Institution and funded jointly by NASA, Atomic Energy Commission, Department of Defense, National Science Foundation, Public Health Service, and Veterans Administration.

Technical Dictionary -- NASA is preparing a dictionary of astronautics, rocketry, and space sciences. It has been determining the words to be included, and assembling definitions agreed upon by responsible technical and scientific organizations. The primary definition for each term will be that adopted by competent societies or international agencies.

Publications

During the period of this report, NASA distributed to news media and other requesters four publications, three new and one revised. These included NASA's Third Semiannual Report to Congress, October 1, 1959 -- March 31, 1960 which the President signed on August 30, 1960; NASA - Spearhead to Space, a booklet to aid recruitment of scientists; The Why of Space Exploration, a resume of practical values of

the nation's space program; and Selling to NASA, a revision of a booklet widely distributed to industry. NASA also published and distributed unclassified portions of the NASA-Industry Conferences (see Chapter 17, Procurement, Contracts, and Grants, pp. 204).

Motion Pictures

Four NASA films were either competitively selected for showing at international film festivals or received other international screenings.

1) "TIROS, Experimental Weather Satellite" (16-mm, sound, color, 13½ minutes)-- This film was featured on September 2 at the Fourteenth Edinburgh Film Festival, Edinburgh, Scotland. On August 30, the film was specially screened for Sir Edward Appleton, Principal, University of Edinburgh, at his request. The judges of the Scientific-Didactic Film Festival, University of Padua, also selected the film for exhibition in Padua, Italy, on October 30 - November 4.

2) "Project Echo" (16-mm, sound, color, 27 minutes) -- Although not completed in time for official judging at the Edinburgh Film Festival, this film was selected for a supplemental screening in the festival.

3) "Chemistry of Meteor Vaporization" (16-mm, sound, color, 29 minutes) -- This film has been selected for screening at the University of Padua Scientific-Didactic Film Festival which will be held October 30 - November 4, 1960. The film was also exhibited at the Eleventh Astronautical Congress in Stockholm, Sweden, held August 15 - 20, 1960. Chemistry of Meteor Vaporization features a lecture by C. Frederick Hansen of Ames Research Center.

4) "Saturn, Workhorse of Outer Space" (16-mm, sound, color, 14 minutes) -- NASA exhibited this film at the Eleventh International Astronautical Congress. It describes NASA Project Saturn, the development of a 1.5-million-pound-thrust clustered launch vehicle.

Films Available to Public -- These and other NASA films are available for loan to educational institutions and other organizations. Borrowers pay only transportation and insurance costs; there is no rental fee. Requests for films and for information concerning them should be addressed to the Technical Information Division (Code ETV), Office of Technical Information and Educational Programs, National Aeronautics and Space Administration, Washington 25, D. C.

Exhibits

The U.S. Information Agency (USIA) and the Department of Commerce's Office of International Trade Fairs (OTIF) have displayed in this country and abroad 12 identical exhibits constructed by NASA. Each exhibit features a life-size model of the TIROS I weather satellite with a transparent plastic shell through which interior equipment (color keyed to a 19 by 8 foot panel containing explanatory copy and photographs) can be viewed. There is also a small scale model of Thor-Able, the TIROS launch vehicle.

An eight-foot-diameter world globe, encircled by vari-colored steel tubing depicting orbits of all successful satellites, was featured in a NASA exhibition in September at the New York City Coliseum during the symposium of the Instrument Society of America. The globe was surrounded by a circular counter with 24 illustrations and other material describing space exploration.

At the request of the Department of State, NASA has prepared a 10-panel exhibit on U.S. civilian space activities for the International Trade Fair to be held in Montreal, Canada, October 25 - November 5, 1960. The exhibit features the same world globe, and includes models and illustrations of tracking and data acquisition stations, sounding rockets, and payloads and launch vehicles of the following experiments: Vanguard satellites I, II, and III; Explorer satellites I, III, IV, VI, and VII; Pioneer space probes IV and V; TIROS I meteorological satellite; and Echo I passive communications satellite.

APPENDICES

APPENDIX A

MEMBERSHIPS OF CONGRESSIONAL COMMITTEES ON AERONAUTICS AND SPACE (April 1, 1960 through September 30, 1960)

SENATE COMMITTEE ON AERONAUTICAL AND SPACE SCIENCES

Lyndon B. Johnson, Tex., Chairman	Styles Bridges, N. H.
Richard B. Russell, Ga.	Alexander Wiley, Wis.
Warren G. Magnuson, Wash.	Margaret Chase Smith, Maine
Clinton P. Anderson, N. Mex.	Thomas E. Martin, Iowa
Robert S. Kerr, Okla.	Clifford P. Case, N. J.
Stuart Symington, Mo.	
John Stennis, Miss.	
Stephen M. Young, Ohio	
Thomas J. Dodd, Conn.	
Howard W. Cannon, Nev.	

HOUSE COMMITTEE ON SCIENCE AND ASTRONAUTICS

Overton Brooks, La., Chairman	Joseph W. Martin, Jr., Mass.
John W. McCormack, Mass.	James G. Fulton, Pa.
George P. Miller, Calif.	Gordon L. McDonough, Calif.
Olin E. Teague, Tex.	J. Edgar Chenoweth, Colo.
Victor L. Anfuso, N. Y.	Frank C. Osmers, Jr., N. J.
B. F. Sisk, Calif.	William K. Van Pelt, Wis.
Erwin Mitchell, Ga.	A. D. Baumhart, Jr., Ohio
James M. Quigley, Pa.	Perkins Bass, N. H.
Leonard G. Wolfe, Iowa	R. Walter Riehlman, N. Y.
Joseph E. Karth, Minn.	
Ken Hechler, W. Va.	
Emilio G. Daddario, Conn.	
Walter H. Moeller, Ohio	
David S. King, Utah	
J. Edward Roush, Ind.	
Thomas G. Morris, N. Mex.	

APPENDIX B

MEMBERSHIP OF THE NATIONAL AERONAUTICS AND SPACE COUNCIL (April 1, 1960 through September 30, 1960)

PRESIDENT DWIGHT D. EISENHOWER, CHAIRMAN

Christian A. Herter
Secretary of State

Thomas S. Gates, Jr.
Secretary of Defense

John A. McCone
Chairman, Atomic
Energy Commission

T. Keith Glennan
Administrator, National
Aeronautics and
Space Administration

Detlev W. Bronk
President, National
Academy of Sciences

Alan T. Waterman
Director, National
Science Foundation

John T. Rettaliata
President, Illinois
Institute of Technology,
Chicago, Ill.

**

Acting Secretary
David Z. Beckler

** One vacancy - member from private life.

APPENDIX C

MEMBERSHIP OF THE NASA--DOD AERONAUTICS AND ASTRONAUTICS COORDINATING BOARD (INCLUDING PANEL VICE-CHAIRMAN)*

Co-Chairmen

Dr. Herbert F. York, Director of Defense Research and
Engineering
Dr. Hugh L. Dryden, Deputy Administrator, NASA

Members-at-large

Dr. Robert C. Seamans, Jr., Associate Administrator, NASA
(Vacancy), Deputy Associate Administrator, NASA
(Alternate to Dr. Seamans)
Mr. Richard S. Morse, Director of Research and Development,
Department of the Army
Lt. General A. G. Trudeau, Chief of Research and Development,
Department of the Army (Alternate to Mr. Morse)

Manned Space Flight Panel

Board Member & Chairman - Dr. Abe Silverstein
Director of Space Flight Programs, NASA
Vice Chairman - Dr. Courtland D. Perkins
Assistant Secretary of the Air Force (R&D)

Unmanned Spacecraft Panel

Board Member & Chairman - Dr. Homer E. Newell
Deputy Director of Space Flight Programs,
NASA
Vice Chairman - Mr. John H. Rubel
Deputy Director of Defense Research and
Engineering

Launch Vehicles Panel

Board Member & Chairman - Dr. Courtland D. Perkins
Assistant Secretary of the Air Force (R&D)
Vice Chairman - Major General Don R. Ostrander, USAF
Director of Launch Vehicles Programs, NASA

* The Board was established September 13, 1960

Space Flight Ground Environment Panel

Board Member & Chairman - Lt. General Donald N. Yates, USAF
Deputy Director of Defense Research
and Engineering
Vice Chairman - Dr. Abe Silverstein
Director of Space Flight Programs, NASA

Supporting Space Research and Technology Panel

Board Member & Chairman - Mr. Ira H. Abbott
Director of Advanced Research Programs,
NASA
Vice Chairman - Mr. John B. Macauley
Deputy Director of Defense Research
and Engineering

Aeronautics Panel

Board Member & Chairman - Vice Admiral John T. Hayward, USN
Deputy Chief of Naval Operations
(Development)
Vice Chairman - Mr. Milton B. Ames
Deputy Director of Advanced Research
Programs, NASA

Secretariat

Secretary for DOD - Mr. Alvin G. Waggoner
Office of the Director of Defense
Research and Engineering, OSD
Secretary for NASA - Mr. William J. Underwood
Office of the Administrator, NASA

APPENDIX D

MEMBERSHIP OF THE CIVILIAN-MILITARY LIAISON COMMITTEE (April 1, 1960 through September 30, 1960)

William M. Holaday,* Chairman

William J. Underwood, Assistant to the Chairman and Secretary

NASA MEMBERS

Hugh L. Dryden, Deputy Administrator
Abe Silverstein, Director of Space Flight Programs
Homer J. Stewart, Director of Program Planning and Evaluation
Ira H. Abbott, Director of Advanced Research Programs

NASA ALTERNATES

DeMarquis D. Wyatt, Assistant Director, Program Planning and
Coordination
Abraham Hyatt, Deputy Director, Launch Vehicle Programs

DEPARTMENT OF DEFENSE (DOD) MEMBERS

Roy W. Johnson, OSD, Director, Advanced Research Projects Agency
John B. Macauley, Deputy Director of Defense Research and
Engineering
Maj. Gen. W. W. Dick, Deputy Chief of Research and Development,
Department of the Army
Vice Adm. R. B. Pirie, Navy, Deputy Chief of Naval Operations (Air)
Brig. Gen. Homer A. Boushey, Commander, Arnold Engineering
Development Center, Air Force, Tullahoma, Tenn.

DOD ALTERNATES

A. G. Waggoner, Assistant Director, Defense Research and
Engineering (Ranges and Space Ground Support)
Col. Charles G. Patterson, Deputy Director of Special Weapons
Office, Chief of Research and Development, Department of the
Army
Rear Adm. K. S. Masterson, Director, Guided Missiles, Office,
Chief of Naval Operations
Col. John L. Martin, Jr., Deputy Director of Missiles and Space
Systems, Office, Secretary of the Air Force

* Resigned April 30, 1960.

APPENDIX E

MEMBERSHIP OF NASA COMMITTEE ON LONG RANGE STUDIES (April 1, 1960 through September 30, 1960)

John A. Johnson, General Counsel, Chairman

Arnold W. Frutkin, Director of International Programs

Homer J. Stewart, Director of Program Planning and Evaluation

Robert G. Nunn, Jr., Special Assistant to the Administrator

Wesley J. Hjernevik, Deputy Director of Business Administration

Jack C. Oppenheimer, Executive Secretary

APPENDIX F

MEMBERSHIP OF NASA INVENTIONS AND CONTRIBUTIONS BOARD (April 1, 1960 through September 30, 1960)

Robert E. Littell, Assistant to the Director of Advanced Research Programs, Chairman

Paul G. Dembling, Assistant General Counsel, Vice-Chairman

Elliott Mitchell, Assistant Director for Propulsion, Office of Launch Vehicle Programs, Member

J. Allen Crocker, Chief, Program Coordination, Lunar and Planetary Programs, Office of Space Flight Programs, Member

C. Guy Ferguson, Assistant Classification and Organization Officer, Personnel Division, Office of Business Administration, Member

James A. Hootman, Secretary

APPENDIX G

MEMBERSHIP OF
NASA ADVISORY COMMITTEE
ON SPACE MEDICAL AND BEHAVIORAL SCIENCES
(April 1, 1960 through September 30, 1960)

Robert S. Morison, M. D.,
Chairman
Director
Medical and Natural Sciences
The Rockefeller Foundation
49 West 49th Street
New York 20, New York

Dr. Frank A. Beach
Professor of Psychology
University of California
Berkeley 4, California

Webb E. Haymaker, M. D.
Chief, Neuropathology Branch
Armed Forces Institute of
Pathology
Washington 25, D. C.

Robert B. Livingston, M. D.
Director, Basic Research
National Institute of Mental
Health
National Institutes of Health
Bethesda 14, Maryland

Col. Charles H. Roadman, MC, USAF -- NASA, Secretary

Dr. George A. Miller
Department of Psychology
Harvard University
Cambridge 38, Massachusetts

Dr. Nello Pace
Professor of Physiology
Department of Physiology
University of California
Berkeley 4, California

Stanley J. Sarnoff, M. D.
Chief, Laboratory of
Cardiovascular Physiology
National Heart Institute
National Institutes of Health
Bethesda 14, Maryland

Dr. Stewart G. Wolf, Jr.
Professor and Head
Department of Medicine
The University of Oklahoma
Medical Center
800 Northeast Thirteenth Street
Oklahoma City 4, Oklahoma

APPENDIX H

MEMBERSHIP OF NASA ADVISORY COMMITTEE ON SPACE BIOLOGY (April 1, 1960 through September 30, 1960)

Dr. Melvin Calvin, Chairman
Professor of Chemistry
University of California
Berkeley 4, California

Dr. Henry Linschitz
Department of Chemistry
Brandeis University
Waltham, Massachusetts

Dr. Philip Abelson
Geophysical Laboratory
Carnegie Institution of
Washington
2801 Upton Street
Washington 8, D. C.

Dr. C. S. Pittendrigh
Department of Biology
Princeton University
P. O. Box 704
Princeton, New Jersey

Dr. Sidney W. Fox
Oceanographic Institute
Florida State University
Tallahassee, Florida

Dr. Carl E. Sagan
Department of Astronomy
University of California
Berkeley 4, California

Dr. Norman H. Horowitz
Professor of Biology
Division of Biology
California Institute of Technology
Pasadena 4, California

Dr. Richard S. Young -- NASA, Secretary

APPENDIX I

MEMBERSHIP OF NASA ADVISORY COMMITTEE ON FLIGHT MEDICINE AND BIOLOGY (April 1, 1960 through September 30, 1960)

W. Randolph Lovelace II, M. D.
Chairman
The Lovelace Foundation
4800 Gibson Boulevard, S. E.
Albuquerque, New Mexico

Mr. Adolph Bialecki
Head, Chemical Engineering
Section
Research and Development
Department
Electric Boat Company
Groton, Connecticut

Lt. Col. Joseph A. Connor, Jr.,
MC, USAF
Chairman, Aerospace Nuclear
Safety Board
Division of Reactor Development
U. S. Atomic Energy Commission
Washington 25, D. C.

Mr. A. Scott Crossfield
Chief Engineering Test Pilot
North American Aviation, Inc.
International Airport
Los Angeles 45, California

Brig. Gen. Don D. Flickinger,
MC, USAF
Assistant for Bioastronautics
Headquarters, ARDC
Andrews Air Force Base, Maryland

G. Dale Smith -- NASA, Secretary

Robert Galambos, M. D.
Chief, Department of
Neurophysiology
Walter Reed Army Institute of
Research
Washington 12, D. C.

Capt. Clifford P. Phoebus, MC,
USN
Director of Astronautics
Bureau of Medicine and Surgery
Department of the Navy
Washington 25, D. C.

Hennig von Gierke, Ph.D.
Chief, Bioacoustics Branch
Biomedical Laboratory
Aerospace Medical Division
Wright Air Development Division
Wright-Patterson Air Force
Base, Ohio

Dr. Alexander C. Williams
Senior Project Engineer
Engineering Project Management
Hughes Aircraft Company
Culver City, California

APPENDIX J

MEMBERSHIPS OF NASA SPACE SCIENCES STEERING COMMITTEE AND SUBCOMMITTEES (September 30, 1960)

	<u>PAGE</u>
STEERING COMMITTEE	
AERONOMY SUBCOMMITTEE	
ASTRONOMY SUBCOMMITTEE	
BIOSCIENCE SUBCOMMITTEE	
IONOSPHERIC PHYSICS SUBCOMMITTEE	
LUNAR SCIENCES SUBCOMMITTEE	
PARTICLES AND FIELDS SUBCOMMITTEE	
PLANETARY AND INTERPLANETARY SCIENCES SUBCOMMITTEE	

SPACE SCIENCES STEERING COMMITTEE*

Chairman : Homer E. Newell

Executive Secretary : Henry E. Stauss

Members : John F. Clark
Edgar M. Cortright
Freeman H. Quimby
Morton J. Stoller

Liaison : E. C. Buckley (H. R. Brockett)**
Abraham Hyatt (E. W. Hall)
N. D. Sanders (Morris Tepper)

SUBCOMMITTEES*

Aeronomy

Chairman : Morris Tepper

Secretary : Mason T. Charak

Members : Charles A. Barth
Maurice Dubin
Harry E. Press
Nelson W. Spencer
William G. Stroud

Liaison : Spencer Frary (MSFC)***
C. Frederick Hansen (Ames)
Richard A. Hord (Langley)
Andrew E. Potter, Jr. (Lewis)

Consultant : Dr. William W. Kellogg, Engineering
Division, RAND Corporation, Santa
Monica, Calif.

* Committee and subcommittee members are on the NASA staff.
Consultants are identified by the organization with which they are
associated.

** The second individual is an alternate.

*** NASA center with which liaison is carried out is shown in
parentheses.

**** Other appointments being processed.

Astronomy

Chairman : Nancy G. Roman

Secretary : Ernest J. Ott

Members : Robert Coates
James E. Kupperian
John C. Lindsay
Raymond Newburn
John A. O'Keefe

Liaison : David Adamson (Langley)
William E. Brunk (Lewis)
Robert T. Jones (Ames)
Charles Lundquist (MSFC)

Consultants : Dr. Dirk Brouwer
Yale University Observatory
New Haven, Conn.

Prof. William F. Fowler
Department of Physics
California Institute of Technology
Pasadena, Calif.

Dr. David S. Heechee
National Radio Astronomy Observatory
Green Bank, W. Va.

Dr. A. Keith Pierce
Associate Director of Solar Astronomy
Kitt Peak National Observatory
Tucson, Ariz.

Dr. Bengt Stromgren
Institute for Advanced Studies
Princeton, N. J.

Dr. Richard Tousey
U. S. Naval Research Laboratory
Washington, D. C.

Bioscience

Chairman : Freeman H. Quimby

Secretary : Richard S. Young

Members	:	S. J. Gerathewohl G. J. Jacobs Jack Posner G. D. Smith
Consultants	:	Dr. Philip H. Abelson Geophysical Laboratory Carnegie Institution of Washington Washington, D. C. Dr. Melvin Calvin Professor of Chemistry University of California Berkeley, Calif. Dr. Sidney W. Fox Oceanographic Institute Florida State University Tallahassee, Fla. Dr. Norman H. Horowitz Division of Biology California Institute of Technology Pasadena, Calif. Dr. Henry Linschitz Department of Chemistry Brandeis University Waltham, Mass. Dr. C. S. Pittendrigh Department of Biology Princeton University Princeton, N. J. Dr. Ernest C. Pollard College of Chemistry and Physics Pennsylvania State University University Park, Pa. Dr. Carl E. Sagan Department of Astronomy University of California Berkeley, Calif.

Ionospheric Physics

Chairman	:	John F. Clark
----------	---	---------------

Secretary	:	Frederick C. Gracely
Members	:	Robert E. Bourdeau Otto Hoberg John E. Jackson Leonard Jaffe
Liaison	:	Gabriel Allen (Lewis) Otto Hoberg (MSFC) John R. Spreiter (Ames) George P. Wood (Langley)
Consultants	:	Prof. Robert A. Helliwell Department of Electrical Engineering Stanford University Stanford, Calif.
		Dr. Hans E. Hinteregger Air Force Research Division Laurence G. Hanscom Field Bedford, Mass.
		Dr. Francis S. Johnson Lockheed Missiles and Space Division Palo Alto, Calif.
		Dr. C. Gordon Little, Chief Upper Atmosphere and Space Physics Division U. S. Department of Commerce National Bureau of Standards Boulder, Colo.
		Dr. E. R. Schmerling Ionosphere Research Laboratory Pennsylvania State University University Park, Pa.
		Prof. George W. Swenson, Jr. Department of Electrical Engineering University of Illinois Urbana, Ill.

Lunar Sciences

Chairman	:	Robert Jastrow
Secretary	:	Newton W. Cunningham

Members	:	Phillis Buwalda Manfred Eimer Albert R. Hibbs Gordon MacDonald Leslie H. Meredith Ernst Stuhlinger
Liaison	:	Alex C. Charters (Ames) Earl W. Conrad (Lewis) John C. Houbolt (Langley)
Consultants	:	Dr. Harrison Brown Department of Geological Sciences California Institute of Technology Pasadena, Calif. Dr. Maurice Ewing Lamont Geological Observatory Columbia University Palisades, N. Y. Dr. Thomas Gold Department of Astronomy Cornell University Ithaca, N. Y. Dr. H. H. Hess Department of Geology Princeton University Princeton, N. J. Dr. Frank Press Division of Geological Science California Institute of Technology Pasadena, Calif. Dr. Gordon Tomkins National Institute of Arthritis and Metabolic Disease National Institutes of Health Bethesda, Md. Dr. Harold C. Urey Scripps Institute of Oceanography University of California La Jolla, Calif.

Particles and Fields

Chairman : John E. Naugle

Secretary : Robert F. Fellows

Members : Michel Bader
Joseph C. Cain
Frank B. McDonald
William McDonald
Marchia Neugebauer

Liaison : James W. Blue (Lewis)
Clinton E. Brown (Langley)
Russel Shelton (MSFC)

Consultants : Dr. Kinsey A. Anderson
Physics Department
University of California
Berkeley, Calif.

Dr. Thomas Gold
Department of Astronomy
Cornell University
Ithaca, N. Y.

Dr. Eugene N. Parker
Enrico Fermi Institute for Nuclear
Studies
University of Chicago
Chicago, Ill.

Prof. Bruno B. Rossi
Department of Physics
Massachusetts Institute of Technology
Cambridge, Mass.

Prof. James A. Van Allen
Department of Physics and Astronomy
State University of Iowa
Iowa City, Ia.

Dr. John R. Winckler
School of Physics
University of Minnesota
Minneapolis, Minn.

Planetary and Interplanetary Sciences

Chairman : Homer E. Newell

Secretary : Roger C. Moore

Members : Richard Davies
Maurice Dubin
Manfred Eimer
Albert R. Hibbs
Herman E. LaGow
Gordon MacDonald
Leslie H. Meredith
Richard S. Young

Liaison : Dean R. Chapman (Ames)
Samuel Katzoff (Langley)
Gerald Morrell (Lewis)
Ernst Stuhlinger (Marshall)

Consultants : Dr. Philip H. Abelson
Geophysical Laboratory
Carnegie Institution
Washington, D. C.

Dr. J. W. Chamberlain
Lunar and Planetary Laboratory
University of Arizona
Tucson, Ariz.

Dr. Gerard P. Kuiper
Yerkes Observatory
University of Chicago
Williams Bay, Wis.

Dr. Joshua Lederberg
Department of Genetics
Stanford University
Palo Alto, Calif.

Dr. Edward P. Ney
Department of Physics
University of Minnesota
Minneapolis, Minn.

Dr. Gerhard F. Schilling
RAND Corporation
Santa Monica, Calif.

APPENDIX K

RESEARCH GRANTS AND CONTRACTS

(Initiated from April 1, 1960 through September 30, 1960)

(Contracts have prefix NA; Grants have prefix NSG; transfer of funds to Government laboratories have prefix NTF or R. Earlier Grants and Contracts are listed in APPENDIX L of the Third NASA Semiannual Report to Congress.)

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>ALASKA</u>				
NASw-174	UNIVERSITY OF ALASKA Warning service for solar cosmic ray events	G. C. Reid	7 mos.	\$ 20,000
<u>CALIFORNIA</u>				
NASr-2	RAND CORPORATION Study of nuclear rockets		12½ mos.	129,173
NASr-8	ASTRO RESEARCH CORPORATION Isotensoid design for space structures	H. U. Schuerch	12 mos.	51,140.65
NASw-81 (Amendment)	CALIFORNIA INSTITUTE OF TECHNOLOGY Investigation of the moon with a lunar seismograph station	H. Benioff F. Price	12 mos.	140,000
NSG-30-60	STANFORD UNIVERSITY Investigation of ionospheric electron content and long range radio propagation	O. K. Garriott	12 mos.	94,660

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>CALIFORNIA (Con't)</u>				
NsG-72-60	UNIVERSITY OF CALIFORNIA Plastic properties of ceramic systems	J. A. Pask	12 mos.	\$ 28,000
NsG-81-60	STANFORD UNIVERSITY Technique for experimental exobiological research	J. Lederberg	12 mos.	37,605
NsG-91	UNIVERSITY OF CALIFORNIA Extreme ultraviolet photon absorption in solids	W. C. Walker	28 mos.	32,515
NsG-93-60	STANFORD UNIVERSITY Large deflection buckling of thin shells	Nicholas J. Hoff	24 mos.	95,000
NsG-94-60	UNIVERSITY OF CALIFORNIA Biological systems in interplanetary environments	C. A. Tobias	24 mos.	180,000
NsG-95-60	UNIVERSITY OF CALIFORNIA International conference on mathematical optimization techniques	-	6 mos.	3,290
NsG-97-60	UNIVERSITY OF CALIFORNIA Studies of inert gases in meteorites, X-ray diffraction and gamma ray detection tech- niques for lunar exploration	J. R. Arnold E. Goldbert H. C. Urey	24 mos.	140,801

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>CALIFORNIA (Cont)</u>				
NSG-98-60	UNIVERSITY OF CALIFORNIA Cosmogenic radioactivity of meteorites, cosmic abundances of the elements and structure and composition of extrater- restrial objects	J. R. Arnold H. Suess G.O.S. Arrhenius	24 mos.	\$175,362
NSG-101-61	UNIVERSITY OF CALIFORNIA Reflection spectra as a basis for studying extraterrestrial life	M. Calvin	24 mos.	195,000
NSG-104-61	UNIVERSITY OF CALIFORNIA Detection, collection and study of micro- organisms existing in the upper atmosphere	S. S. Elberg	12 mos.	16,000
JPL Subcontract (No number assigned)	RAND CORPORATION Lunar, planetary and interplanetary studies	-	12 mos.	151,066
<u>COLORADO</u>				
NASw-89 (Amendment)	UNIVERSITY OF COLORADO Study of solar ultraviolet radiation from rockets and satellites (Lyman- Alpha spectrometer for satellite use, and analysis of data)	William Rense	12 mos.	140,000
NSG-92-60	UNIVERSITY OF COLORADO Research and development of new techniques of observation of solar phenomena	Harold Zirin James W. Warwick	24 mos.	97,300

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>COLORADO (Cont.)</u>				
NAS5-6-16	ELECTRIC BOAT DIVISION Engineering approach for a closed cycle photosynthetic system	A. Bialecki	12 mos.	\$150,610
NsG-19-59 (Supplement)	YALE UNIVERSITY Automatic remote analysis and detection of extraterrestrial bacteria	Wolf Vishniac	24 mos.	17,250
NsG-82-60	YALE UNIVERSITY Steady state interaction between radiation and matter in stellar atmospheres	Rupert Wildt	12 mos.	13,621
<u>DISTRICT OF COLUMBIA</u>				
NsG-51-60 (Supplement)	SMITHSONIAN INSTITUTION Design and construction of equipment for an ultraviolet sky survey to be conducted from a stabilized satellite	F. L. Whipple	3 mos.	215,000
NsG-87-60 (Supplement)	SMITHSONIAN INSTITUTION Optical satellite tracking program	F. Whipple	4 mos.	400,000
NsG-102-61	SMITHSONIAN INSTITUTION Support of the bioscience information exchange	Stella L. Deignan	12 mos.	20,000
NTF-106	U. S. WEATHER BUREAU Squall line and severe local storm research project	-	12 mos.	50,000

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>DISTRICT OF COLUMBIA (Con't)</u>				
NTF-108	AIR RESEARCH AND DEVELOPMENT COMMAND Support of ARDC high-altitude balloon program to be flown at approximately 62° magnetic north, starting May 15, 1960		2 mos.	\$ 20,000
NTF-109	AIR RESEARCH AND DEVELOPMENT COMMAND Research in conjunction with AFIP effort in supplying and interpreting nuclear emulsions to be flown in high-altitude balloon flights		2 mos.	16,000
NTF-110	ARMED FORCES INSTITUTE OF PATHOLOGY Pathological studies on mice to be exposed to cosmic radiation in high altitude balloon flights	W. Haymaker	2 mos.	11,840
R-3	LIBRARY OF CONGRESS Compilation of a bibliography of current literature on space life sciences	W. W. Rossiter	36 mos.	61,995
R-4	NATIONAL BUREAU OF STANDARDS Boundary layer transition	G. B. Schubauer	12 mos.	70,000
R-5	NATIONAL BUREAU OF STANDARDS The mechanisms and kinetics of degradation of polymers by ultraviolet radiant energy	F. W. Reinhardt B. G. Achhammer	12 mos.	35,000

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>FLORIDA</u>				
NSG-103-61	FLORIDA STATE UNIVERSITY Space genetics	A. Gib DeBusk	36 mos.	\$166,884
NSG-105-61	FLORIDA STATE UNIVERSITY Research on chemical mechanisms by which life might have begun including considera- tions of chemical and environmental require- ments	Sidney Fox	36 mos.	103,804
<u>NTF-117</u>				
	U. S. NAVAL AVIATION MEDICAL CENTER Pensacola, Florida Life under exotic environmental conditions	D. Beischer	12 mos.	17,000
<u>R-1</u>				
	U. S. NAVAL AVIATION MEDICAL CENTER Pensacola, Florida Research into the effects of angular velocity, angular acceleration, coriolis accelerations, and tumbling on healthy persons and on subjects with decreased or lost function of the semicircular canals.	A. Graybiel	12 mos.	150,440
<u>HAWAII</u>				
NASr-5	UNIVERSITY OF HAWAII Research in the construction and testing of a high resolution rocket spectrograph	H.C. McAllister	24 mos.	39,905

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>ILLINOIS</u>				
NASr-1	ARMOUR RESEARCH FOUNDATION Studies of particulate systems in solarization of algae	J. Rosinski	12 mos.	\$ 21,730
NASw-135	UNIVERSITY OF CHICAGO Explorer VI data reduction and analysis	L. M. Biberman	6 mos.	58,525
NASw-162	UNIVERSITY OF CHICAGO Satellite borne cosmic ray experiments	J. A. Simpson	12 mos.	102,737
NsG-13-59	UNIVERSITY OF ILLINOIS Investigation of the flow and heat transfer conditions within separated flow regions	H. H. Korst	12 mos.	34,402
NsG-24-59	UNIVERSITY OF ILLINOIS Investigation of the ionosphere using signals from earth satellites	G.W.Swenson, Jr.	12 mos.	51,082
NsG-96-60	UNIVERSITY OF CHICAGO Theoretical investigation of further consequences of solar wind	E. N. Parker	12 mos.	24,506
<u>IOWA</u>				
NASw-17 (Amendment)	STATE UNIVERSITY OF IOWA Investigation of corpuscular radiation	J. A. Van Allen	23 mos.	382,000

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>MARYLAND</u>				
R-2	U.S. ARMY BIOLOGICAL LABORATORIES Ft. Detrick, Maryland Research to determine the effects of ethylene oxide on the sterilization of electronic components and other materials used in space vehicles	C. R. Phillips	12 mos.	\$ 30,038
<u>MASSACHUSETTS</u>				
NASw-37 (Amendment)	MASSACHUSETTS INSTITUTE OF TECHNOLOGY Designing, constructing, and testing a high-energy gamma ray detector capable of being carried in a satellite	W. L. Kraushaar	16 mos.	86,020
NASw-75	MASSACHUSETTS INSTITUTE OF TECHNOLOGY Development of apparatus for measurement of plasma density	B. Rossi	12 mos.	97,000
NASw-130 (Amendment)	MASSACHUSETTS INSTITUTE OF TECHNOLOGY Study of the navigation, guidance, and control of an interplanetary vehicle	M. B. Trageser	4 mos.	15,000
NASw-161	MASSACHUSETTS INSTITUTE OF TECHNOLOGY Study of satellite and space probe communication systems	Thomas Rogers	12 mos.	150,000
NASw-168	UNITED RESEARCH INCORPORATED Study of the relations of groups to the process of policy formulation and public information within NASA	D.V. d'Arbeloff	5 mos.	39,703

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>MASSACHUSETTS (Con't)</u>				
NASw-184	HARVARD UNIVERSITY Instruments for an orbiting solar observatory	Leo Goldberg	8 mos.	\$200,000
NsG-89-60	HARVARD UNIVERSITY Multicolor photoelectric photometry and polarimetry of the moon and planets	D. H. Menzel	36 mos.	175,000
NsG-107	MASSACHUSETTS INSTITUTE OF TECHNOLOGY Study of feedback information criteria for functional extension of the human hands	T. B. Sheridan	36 mos.	69,000
J.P.L. Subcontract #950014	HARVARD UNIVERSITY Study of an optical system for a Mars probe	Donald H. Menzel	3 mos.	10,082
<u>MICHIGAN</u>				
NASw-54 (Amendment)	UNIVERSITY OF MICHIGAN Astronomical experiments in satellite- radio astronomy	F. T. Haddock	5 mos.	119,140
NASw-173	UNIVERSITY OF MICHIGAN Control of flow characteristics of components of fuel systems for missiles and conventional power plants	Hadley J. Smith	12 mos.	17,011

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>MICHIGAN (Cont)</u>				
NASw-175	UNIVERSITY OF MICHIGAN Laboratory and flight test of develop- mental pressure transducers	D. R. Tausch	12 mos.	\$ 20,000
NASw-115	UNIVERSITY OF MICHIGAN Rocket grenade instrumentation program	H. F. Allen	24 mos.	300,000
NsG-86-60	UNIVERSITY OF MICHIGAN Study of particle dynamics under conditions which exist in rockets	R. B. Morrison	12 mos.	12,000
<u>MINNESOTA</u>				
NASw-56 (Amendment)	UNIVERSITY OF MINNESOTA Cosmic ray instrumentation in satellites and planetary probe experiments	J. R. Winckler	11 mos.	168,000
NsG-83-60	UNIVERSITY OF MINNESOTA Study of real gas effects at hypersonic air velocities and temperatures up to 4500 degrees R	Rudolf Hermann	24 mos.	80,000
NsG-109-61	UNIVERSITY OF MINNESOTA High altitude balloon monitoring for cosmic rays and solar terrestrial phenomena	John R. Winckler Edward P. Ney	12 mos.	105,000

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>NEW JERSEY</u>				
NASw-117	ISOMET CORPORATION Oxygen from dissociation of carbon dioxide	W. Ruderman	12 mos.	\$100,877
NASw-178	THERMIONIC PRODUCTS COMPANY Investigation to determine the effects of controlled thermal treatment in re- active gaseous atmosphere on molybdenum and titanium-molybdenum	V. O. Allen	12 mos.	42,224
<u>NEW YORK</u>				
NASr-3	PRINCETON UNIVERSITY Research on moderate dispersion rocket spectrophotometry	L. Spitzer	18 mos.	300,000
NsG-99-60	PRINCETON UNIVERSITY Nonlinear aspects of combustion instability in liquid propellant rocket motors	L. Crocco	16 mos.	135,954
<u>NEW YORK</u>				
NASw-82 (Amendment)	COLUMBIA UNIVERSITY Investigation of a lunar seismograph system	M. Ewing	12 mos.	125,000
NASw-167	UNIVERSITY OF ROCHESTER Research in solar and cosmic ray physics	E. M. Hafner	12 mos.	46,800
NASw-181	UNIVERSITY OF ROCHESTER Study of a space chamber and related solar radiation simulator	D. W. Healey	12 mos.	40,000

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>NEW YORK (Con't)</u>				
NsG-9-59 (Supplement)	NEW YORK UNIVERSITY Investigation of the feasibility of the production of breathing oxygen from space minerals	E. R. Kaiser K. L. Komarek	12 mos.	\$ 50,000
NsG-88-60	CORNELL UNIVERSITY Theoretical radiophysics studies	Thomas Gold	3 mos.	8,000
NsG-90-60	NEW YORK UNIVERSITY Investigation of the effect of pressure on metallurgical phenomena	Harold Margolin I. B. Cadoff	28 mos.	59,000
NsG-100-60	RENSELAER POLYTECHNIC INSTITUTE Interdisciplinary materials research program	S. E. Wiberley	36 mos.	300,000
NsG-108-61	NEW YORK UNIVERSITY Study of geophysical aspects of hydro- magnetic waves	A. Beiser	12 mos.	34,084
<u>OKLAHOMA</u>				
NASr-4	OKLAHOMA STATE UNIVERSITY Research development of transistorized 15-channel pulse-time telemeter	-	9 mos.	40,000
NASr-7	OKLAHOMA STATE UNIVERSITY Analytical study of meteorite impact on coated photomultiplier	F. C. Todd	12 mos.	30,190

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>PENNSYLVANIA</u>				
NASw-90	MINE SAFETY APPLIANCES COMPANY Investigation of superoxide or air regeneration chemicals for closed compartments	J.W. Maustellar	12 mos.	\$ 72,363
NASw-127 (Amendment)	GENERAL ELECTRIC Study and purification of water from biological wastes	-	15 mos.	59,080
NASw-170	DECKER CORPORATION Determination of the approximate age of the most recent features of the moon	I. M. Leavitt	12 mos.	14,700
NSG-84-60	TEMPLE UNIVERSITY The production of hypervelocity particles of small size and to increase the sensitivity of micrometeorite detection techniques	J. L. Bohn	12 mos.	30,856
NSG-85-60	PENNSYLVANIA STATE UNIVERSITY Investigation of cavitation inception	G.F. Wislicenus	24 mos.	84,860
<u>VIRGINIA</u>				
NSG-106-61	COLLEGE OF WILLIAM AND MARY Research on radio spectroscopy of magnetized frequency and microwave plasmas	F.R. Crownfield D. E. McLennan	24 mos.	67,200

<u>Grant or Contract Number</u>	<u>Organization and Purpose</u>	<u>Principal Investigator</u>	<u>Duration</u>	<u>Amount</u>
<u>WISCONSIN</u>				
NASw-66 (Amendment)	UNIVERSITY OF WISCONSIN Stellar spectra-photometry in the far far ultraviolet, including preliminary design studies of a satellite-borne telescope and consideration of data recovery and processing problems	A. D. Code	13 mcs.	\$104,992
<u>FOREIGN - GERMANY</u>				
NSG-45-60 (Supplement)	UNIVERSITY OF HEIDELBERG Recording and analysis of information transmitted from a composite radiation satellite	H. J. Langmann	-	5,800

APPENDIX L

R&D CONTRACTS OR AMENDMENTS THEREOF OF \$100,000 AND OVER SHOWN BY PROGRAM* (APRIL 1, 1960 THROUGH SEPTEMBER 30, 1960)

ACTIVITY: NASA HEADQUARTERS

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Advanced Research Programs Support of NASA plant	NASw-145	Original contract for management and program control system.	Thompson Ramo Wooldridge, Inc.	\$ 102,141
	NASw-186	Motion picture services for NASA for the fiscal year 1961.	Byron Motion Pictures, Inc.	120,000
Vehicle Development Saturn	NASw-160	Reliability study.	ARINC Research Corp.	144,214

ACTIVITY - LANGLEY RESEARCH CENTER

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Advanced Research Programs Support of NASA plant	NASL-754	D-61 modification of Argo D-4 (Javelin) vehicle.	Aerolab-Development Co.	\$ 113,060
	S-3434	Rental of electric accounting machines and electronic data processing machines.	International Business Machines Corp.	457,888

* Some contracts are apportioned over more than one program, and the contract obligation for a particular program may be less than \$100,000. However, the total amount of the contract aggregates at least \$100,000.

** Amounts shown in this column on this and following pages represent obligations incurred during this report period only.

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
	L-79877	Oil, fuel, No. 6 burner, for transport truck delivery Aug. 1, 1960 thru July 31, 1961.	Reese Oil Corp.	\$ 156,158
Satellite Applications Communications	L-55931	Manufacture, loading, and delivery XM45, modified XM20 and TX-76 igniters. Funding for an additional three XM33-E8 Castor rocket motors.	U. S. Army Ordnance Missile Command	138,240
Manned Space Flight	NAS1-229	Engineering investigations, plans, and participation in phases of ground instrumentation testing for Project Mercury range.	Massachusetts Institute of Technology	600,000
	NAS1-430	Project Mercury tracking and ground instrumentation system.	Western Electric Co., Inc.	800,000
	NAS5-128	Antennas and receivers.	Simmonds Precision Products, Inc.	175,665
	NAS5-154	90 receivers, homing -- Pulse and CW modes. Project Mercury, recovery operations.	I. T. T. Kellogg Space Communications Lab.	100,000
	L-55931-G	Manufacture, loading and delivery of XM45, modified XM20 and TX-76 igniters.	U. S. Army Ordnance Missile Command	43,847

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Vehicle Development Scout	NAS1-553	Design, develop, fabricate eight 609A vehicle launchers and ground support equipment.	Chance-Vought Aircraft, Inc.	\$ 100,000
	NAS1-585	Rocket motors, tests and transtainers.	Aerojet-General Corp.	855,347
	NAS1-900	Design, development, assembly and checkout for launching five Scout vehicles.	Chance-Vought Aircraft, Inc.	700,000
	L77203	Solid propellant, Castor, rocket motors for Scout propulsion. Increased requirement of four motors.	U. S. Army Ordnance Missile Command	191,042
Supporting Activities Tracking and data acquisition	NAS1-229	Engineering investigations, plans, and participation in phases of ground instrumentation testing for Project Mercury range.	Massachusetts Institute of Technology	150,000
	NAS1-707	Communication services-Project Mercury	Radio Corp. of America	181,650

ACTIVITY - AMES RESEARCH CENTER

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Advanced Research Programs Support of NASA plant	NAS2-276	Rebuilding of VZ-3RY	Ryan Aeronautical Co.	\$ 150,402

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
	NAS2-292	Analog computer system	Electronic Associates, Inc.	\$ 355,125
	NAS2-293	Ion accelerator for extension of energy range.	Applied Radiation Corp.	170,575
	A-12220	Rental of I.B.M. 704 Processing System for fiscal year 1961.	International Business Machines Corp.	525,180

ACTIVITY - LEWIS RESEARCH CENTER

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Advanced Research Programs Support of NASA plant	NAS3-906	Amplifiers.	Electro Instruments, Inc.	\$ 195,914

ACTIVITY - GODDARD SPACE FLIGHT CENTER

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Advanced Research Programs Support of NASA plant	S-5462-G	In-plant shop services to support the NASA Goddard Space Flight Center during fiscal year 1961.	Naval Weapons Plant	\$ 200,000
	S-7587-G	Overhead cost for tenancy	U. S. Naval Research Lab.	550,000

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Scientific Investigations in Space Sounding rockets	NAS5-253	Minitrack field services and related support.	The Regents of the New Mexico College of Agriculture and Mechanic Arts	\$ 400,810
	NAS5-299	Design and fabricate attitude control system.	Aerojet-General Corp.	246,104
	S-8171-G	Continuation of advanced technical development in vibration studies in accordance with NRL Problem D01-61, during FY 61.	Naval Research Laboratory	106,000
Scientific Investigations in Space Scientific satellites	NASw-113	Satellite-borne solar pointing control.	Ball Brothers Research Corp.	200,000
	NAS5-253	Minitrack field services and related support.	The Regents of the New Mexico College of Agriculture and Mechanic Arts	105,500
	NAS5-270	Instrumentation for the determination of the composition of the upper atmosphere.	Geophysics Corp. of America	372,568
	NAS5-276	Theoretical study of certain aspects of the earth's magnetic field and the space environment near the earth.	The Rand Corp.	114,441
	NAS5-403	Airborne ground checkout equipment for ionosphere sounder system.	Airborne Instruments Lab., Div. of Cutler-Hammer, Inc.	269,808

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Scientific Investigations in Space Scientific eatellites	NAS5-581	S-6 satellite structure	The Budd Co.	\$ 159,894
	S-7598-G	Installation and operation of an ionosphere sounding station.	National Bureau of Standards.	125,000
	S-7775-G	To procure five prototype mass spectrometers and nine flight mass spectrometers with appropriate converters.	Office of Naval Research	225,000
	S-7964-G	Construct, install and use 35-foot vacuum spectrograph for the study of the far ultraviolet spectra of atoms and molecules of astrophysical interest.	National Bureau of Standards	150,000
Scientific Investigations in Space Lunar and planetary exploration	NAS5-253	Minitrack field services and related support.	The Regents of the New Mexico College of Agriculture and Mechanic Arts	3,000
	S-2365-G	Additional funding to the Atlas-Able V program.	Air Research and Development Command	5,335,000
	S-7780-G	Investigate geochemical and petrographic properties of tektites and meteorites, initiate photographic mapping studies which will lead to detailed mapping of selected lunar areas.	Geological Survey U. S. Department of the Interior	205,000

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Scientific Investigations in Space Vanguard	NAS5-253	Minitrack field services and related support.	The Regents of the New Mexico College of Agriculture and Mechanic Arts	\$ 15,000
Satellite Applications Meteorology	NAS5-253	Minitrack field services and related support.	The Regents of the New Mexico College of Agriculture and Mechanic Arts	12,000
	NAS5-434	Design, develop, fabricate, acceptance test and deliver a laboratory model of an Electrostatic Tape Television Satellite.	Radio Corporation of America Astro Electronic Products Div.	302,324
	NAS5-478	Infra-red radiation experiment integration, modifications to ground stations and pre/post launch support for the Tiros II meteorological satellite.	Radio Corporation of America Astro Electronic Products Div.	947,908
	S-4796-G	Develop and deliver 30 transistors.	U. S. Army Signal Research & Development Laboratory	150,000
	S-7607-G	Accelerated completion of the PMR ground station support for TIROS II.	Pacific Missile Range	120,000
Manned Space Flight	NAS5-59	Project Mercury capsule, spare parts, ground support equipment, training aids, technical data and other matters related thereto.	McDonnell Aircraft Corp.	7,033,628

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Manned Space Flight	HS-36	Atlas Booster Program for Project Mercury.	Air Force Ballistic Missile Div.	\$10,000,000
	S-3584-G	Recovery operations and training.	Bureau of Weapons	250,000
	S-3585-G	Recovery operations and training.	Bureau of Ships, Dept. of Navy	200,000
	S-3652-G	Logistic support.	Air Force Missile Test Center	113,000
	S-3653-G	Range support.	Air Force Missile Test Center	1,991,000
	S-3654-G	Range support.	Army Ordnance Missile Command, White Sands Missile Range	460,000
	S-3655-G	Range support.	Pacific Missile Range United States Naval Missile Center	345,000
	S-3659-G	Recovery operations - training support for Project Mercury.	Bureau of Weapons	1,500,000
	S-3660-G	Recovery operations - Military support for Project Mercury by the Bureau of Ships.	Bureau of Ships	1,500,000
	S-7201-G	Continuation of computing services under ONR Contract Nonr-2169(00) with IBM, thru June 30, 1961.	Naval Research Laboratory	212,000

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Vehicle Systems Technology	S-4601-G	Initial procurement from Lockheed Missiles and Space Div., Sunnyvale, Calif., of engineering services and long lead time items for Agena-B Vehicle Program.	Air Research and Development Command	\$ 290,000
Space Propulsion Technology Solid rockets	NAS5-273	Feasibility program for conical segmented rocket motors.	United Technology Corp. United Aircraft Corp.	148,402
	NAS5-295	Development of lithium-cooled rocket engine exhaust nozzle.	North American Aviation, Inc. Rocketdyne Div.	206,861
	NAS5-482	Solid fuel rocket attitude control system.	Vickers, Inc.	127,159
	NAS5-483	Attitude and velocity control system of a solid rocket.	General Motors Corp. Allison Div.	199,000
	NAS5-501	Arcan rocket improvement - Advancement in the state-of-the art.	Atlantic Research Corp.	129,963
Space Propulsion Technology Liquid rockets	NASw-16	Development of 1500K rocket engine.	North American Aviation, Inc.	20,200,000
	NAS5-445	Study and demonstrate the feasibility of the plug nozzle concept for a rocket propulsion system.	General Electric Co.	700,000
	S-8297-G	Modifications of existing test facilities at Santa Susana, Calif., for development of 200K pound thrust hydrogen-oxygen engine development project with Rocketdyne.	Air Material Command	1,500,000

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Space Propulsion Technology Nuclear systems technology	NAS5-412	Development of a liquid hydrogen cooled jet nozzle.	North American Aviation, Inc.	\$ 235,185
	NAS5-417	SNAP 8 Nuclear Power Conversion system.	Aerojet General Corp.	1,467,169
	NAS5-453	Investigate the compatibility of high temperature potassium with containment materials.	North American Aviation, Inc. Rocketdyne Div.	256,443
	NAS5-584	Engineering properties of potassium.	Battelle Memorial Institute	124,020
Space Propulsion Technology Space power technology	NAS5-462	Development of the Sunflower solar auxiliary power system.	Thompson Ramo Wooldridge, Inc.	1,000,000
	NAS5-506	30-kilowatt plasmajet rocket engine development.	General Electric Co.	247,119
	NAS5-600	30-kilowatt plasmajet rocket engine development.	Avco Corporation	240,367
	S-2365-G	Study of nickel cadmium batteries.	Air Research and Development Command	135,000
Vehicle Development Delta	S-4737-G	Range overtime, propellants gases, lubricant and chemicals for five vehicle launches.	Air Research and Development Command	587,500

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Supporting Activities Tracking and data acquisition	NAS5-253	Minitrack field services and related support.	The Regents of the New Mexico College of Agri- culture and Mechanic Arts	\$ 92,503
	NAS5-492	Antenna, switchable model, YG-3000/CP-9A and spare parts.	All Products Co.	137,117
	NAS5-538	Ampex Model FR-607 high performance magnetic tape recorder reproducers.	Ampex Data Products Co.	229,142
	NTF-72	Support of Department of Defense upper atmosphere research facility at Ft. Churchill, Manitoba, Canada.	Department of the Army, Research Development	500,000
	S-2328-G	Communication teletype lines, radio channels and equipment charges.	Department of the Army, Signal Officer	152,000
	S-5461	To procure 4 test sets radio AN/GRM-33, 1 radio transmit- ter, AN/FRT-40, 3 radio trans- mitter, AN/FRT-39.	Bureau of Ships, Depart- ment of the Navy	143,582
	S-7201-G	Continuation of computing services under ONR Contract Nonr-2169(OO) with IBM, through June 30, 1961.	Naval Research Laboratory	300,000

ACTIVITY - WESTERN OPERATIONS OFFICE

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Advanced Research Programs Support of JPL plant	NASw-6	Construction of a facility in accordance with ARPA Order No. 137-60. Project DUB, and Wind Tunnel Test for USAF Samos.	California Institute of Technology	\$ 624,296
Vehicle Development Saturn	NAS7-1	Services and materials for the design, development, fabrication, and test of ten Saturn S-IV stage vehicles.	Douglas Aircraft, Inc.	7,150,133
	NAS7-3	Design, research and development of the NAA H-1 rocket engine.	North American Aviation, Inc. Rocketdyne Div.	2,281,791
	NAS7-4	Fabrication and production of H-1 rocket engine, and related spares and components.	North American Aviation, Inc. Rocketdyne Div.	4,040,000
Supporting Activities Tracking and data acquisition	NASw-6	Construction of a deep space instrumentation facility.	California Institute of Technology	500,000

ACTIVITY - MARSHALL SPACE FLIGHT CENTER

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Advanced Research Programs Support of NASA plant	NAS8-2	Security guard for MSFC	Federal Services, Inc.	100,000

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Advanced Research Programs Support of NASA plant	NAS8-16	Microfilming and operation of facilities in Technical Documentation.	Watland, Inc.	\$ 213,500
	NAS8-35	General computing services.	General Electric Co.	660,000
	NAS8-255	Liquid oxygen & liquid nitrogen.	Linde Company	426,622
	NAS8-443	Contractual services to furnish custodial services.	National Building Maintenance Corp.	280,800
	P.O.H.-1906	Maintenance on LOD facilities at AMR.	Air Force Missile Test Center	190,000
Satellite Applications Meteorology	P.O.H.-3626	Miscellaneous stock items.	Army Ordnance Missile Command	750,000
	P.O.H.-3627	Miscellaneous supplies.	Army Ordnance Missile Command	100,000
	NAS8-6	Engineering services for Saturn, Mercury and Juno programs.	Chrysler Corp.	63,580
	NAS8-17	Maintenance, modification and check-out of electrical equipment.	Reynolds Electrical and Engineering Co.	21,000
	NAS8-18	Engineering, fabrication and other related services.	Hayes Aircraft Corp.	2,298
Manned Space Flight	NAS8-6	Engineering services for Saturn, Mercury and Juno programs.	Chrysler Corp.	40,413

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Manned Space Flight	NAS8-17	Maintenance, modification and check-out of electrical equipment.	Reynolds Electrical and Engineering Co.	\$ 34,000
	NAS8-18	Engineering, fabrication and other related services.	Hayes Aircraft Corp.	20,300
	NAS8-20	Engineering, fabrication and related services.	Brown Engineering Co.	55,576
	NAS8-21	Fabrication services related to Saturn and Mercury programs.	Redstone Machine and Tool Corp.	14,196
	NAS8-23	Fabrication & assembly work & related services.	Spaco Manufacturing Co.	11,285
Space Propulsion Technology Liquid rockets	NAS8-19	Development of 200K-lb. thrust LO2 - LH2 engine.	North American Aviation	5,000,000
Vehicle Development Centaur	NAS8-515	Design, development and fabrication of the Centaur upper stage vehicles and associated equipment.	Air Research and Development Command	10,430,000
Vehicle Development Saturn	NAS8-6	Engineering services for Saturn, Mercury and Juno programs.	Chrysler Corp.	656,252
	NAS8-14	Procurement of XLR-115 engine.	Air Research and Development Command	12,100,000
	NAS8-17	Maintenance, modification and check-out of electrical equipment.	Reynolds Electrical and Engineering Co.	99,000

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Vehicle Development Saturn	NAS8-18	Engineering, fabrication and other related services.	Hayes Aircraft Corp.	\$ 3,247,514
	NAS8-20	Engineering, fabrication and related services.	Brown Engineering Co.	1,572,689
	NAS8-21	Fabrication services related to Saturn and Mercury programs.	Redstone Machine and Tool Corp.	138,438
	NAS8-22	Engineering, fabrication and related services.	Lockheed Aircraft Corp.	502,251
	NAS8-23	Fabrication & assembly work & related services.	Spaco Manufacturing Co.	173,241
	NAS8-24	Development of Saturn C-1 space vehicle.	Air Research and Development Command	120,000
	NAS8-25	Engineering, design, fabrication, installation and related services for tooling manufacture.	Progressive Welder and Machine Co.	150,000
	NAS8-32	Hydrogen semitrailer.	Standard Steel Corp. Cambridge Div.	179,059
	NAS8-34	Engineering, design, fabrication and related services for testing, various items of vent, pressurizing and propellant feed lines.	Pexonics Corp.	750,000
	NAS8-36	Engineering services and support fabrication work.	Fenwal, Inc.	120,003

<u>PROGRAM</u>	<u>CONTRACT NUMBER</u>	<u>PURPOSE</u>	<u>CONTRACTOR</u>	<u>APPROXIMATE OBLIGATIONS**</u>
Vehicle Development Saturn	NAS8-48	Research, development and manufacture of 17.5K rocket engine.	Air Research and Develop- ment Command	\$ 8,000,000
	NAS8-73	Design, manufacturing of components and ground support equipment for Agena program.	Air Research and Develop- ment Command	1,084,000
	NAS8-505	Hydraulic units and compon- ents.	Army Ordnance District	110,000